37. *The* Stockdale Shales. By J. E. Marr, M.A., F.G.S., Fellow of St. John's Coll. Camb., and H. A. Nicholson, M.D., D.Sc., F.G.S., Regius Professor of Natural History in the University of Aberdeen. (Read May 9, 1888.)

[Plate XVI.]

§ 1. Introduction.

We propose, in a series of papers, to supplement the observations which have been previously published upon the divisions, organic remains, and subdivisions of the Lower Palæozoic Rocks of the Lake-district and adjoining areas. In the investigation of the geological structure of any such complicated region as the Lake-district, the first step necessarily consists in the determination of those rock-divisions which are developed in the area in question to an extent which renders them capable of representation on the one-inch map of the Ordnance Survey. When the first step has been satisfactorily accomplished, the *general* structure of the region may be said to be determined; but there may, nevertheless, remain many points of great geological interest and importance which still require solution. Thus, it is now generally recognized that in any region a set of deposits may have been formed so slowly that a thickness of only a few feet of such may mark a lapse of time represented elsewhere by many hundreds of feet of sediment. In such cases a more minute subdivision of the strata than can be represented upon an ordinary geological map becomes necessary, and it is also essential to enter into a detailed examination and comparison of the organic remains of the different beds. By this method of investigation very important results have already been obtained in other regions, and we see no reason to doubt that the application of the same method to the study of the Palæozoic Rocks of the Lake-district will result in the eventual filling up of many of the gaps which at present exist in the geological history of this area.

Under ordinary circumstances it would, no doubt, have been more convenient to commence our investigations with an examination of the oldest rocks of the district, and in selecting the Stockdale Shales as a starting-point we were influenced by several considerations. In the first place, the Stockdale Shales form a well-marked series, readily separable from the rocks lying below and above them, while they present at the same time considerable variations in the character of their sediments and included fossils.

Secondly, the outcrop along their whole range in the Lake-district proper has been marked in the published maps of the Geological Survey. Thirdly, the equivalent and similar rocks in other areas have been described with a minuteness which is wanting in the case of the other series of the Lower Palæozoic rocks of this region; we are therefore likely, by selecting this series, to test the value of these minute subdivisions for purposes of comparison.

The general features of the district have been so frequently described, and its structure is so universally known, that it is sufficient to remark here that the Stockdale Shales occur on the south side of a great anticlinal, and that they do not appear on the north, as the newer rocks of the northern limb are concealed by the unconformable overlap of the Upper Palæozoic rocks. In the southern limb the beds first appear on the eastern side of the Lake-district proper, a few miles to the west of Shap Wells, after which they are traceable with a general E.N.E.–W.S.W. strike over the valleys of Long Sleddale, Kentmere, and Troutbeck, and across the head of Windermere to Coniston Waterhead. In this region they dip, usually at a high angle, to the S.S.E., and their course is interrupted by several large north and south faults, the position of which will be seen by reference to the maps of the Geological Survey. (We would here notice that we do not give a map of the outcrop of the beds, as one on a smaller scale than that of the published geological maps would be insufficient for our purpose.) On the western side of Coniston Lake the strike of the beds changes, trending generally in a N.E.–S.W. direction, and continues thus to Broughton Mills, to the south of which we have seen no trace of the Stockdale Shales, on the western side of the Duddon estuary. On the eastern side of that estuary the beds are brought to the surface by a great anticlinal fold, and appear in the neighbourhood of Dalton-in-Furness, where the exposures are poor. In addition to this the Stockdale Shales are also seen in two areas lying on the eastern margin of the Lake-district,—first in the exposure of Lower Palæozoic which is found between the Pennine fault of the Cross-Fell chain and the New Red Sandstones of the Eden valley, where the beds crop out in the neighbourhood of the village of Knock, in the course of Swindale Beck and its tributary, Rundale Beck. Secondly, in the anticlinal which runs along the Rawthey valley, in the neighbourhood of Sedbergh, where the shales are seen in the bed of the river at Rawthey Bridge, and in several of the tributary streams, as Hebblethwaite Gill, Cross Haw Beck, and Taith's Gill, on the south side of the Rawthey, and in the stream which runs from Spengill Head, on the north side. Representatives of these beds also occur in the neighbourhood of Ingleton in Austwick Beck, and in Teesdale possible equivalents have been described by Messrs. Gunn and Clough.

In most places, owing to the small thickness of the series and the high angle of dip, the outcrop is very narrow. This outcrop is nearly at right angles to the direction of the principal streams, so that there are frequent opportunities of seeing the relations of the

Stockdale Shales to the beds above and below. Against this advantage must be placed the paucity of sections, but especially the constant occurrence of a strike-fault, which frequently cuts out a great part of the series, and, as we shall eventually show, in every case causes a portion to be missing. Nevertheless the number of exposures is sufficient to allow us to piece together the whole of the succession, save, possibly, at one point only, where we shall give reasons for believing that if any portion of the deposit is now entirely unseen in this district, it is only a very insignificant one.

We would record our debt of gratitude to Professor Lapworth for invaluable assistance, and to Professor Hughes for information about the rocks of the Sedbergh district.

§ II. Notice of Previous Writings.

The first attempt at a subdivision of the rocks of the Lake-district was made by Mr. Jonathan Otley, whose paper appeared originally in the 'Lonsdale Magazine,' vol. i. p. 433, and subsequently in the 'Philosophical Magazine' for 1820 (Phil. Mag. vol. lvi. p. 257). Mr. Otley adopted that threefold subdivision of the slates of this area which was afterward supported by Professor Sedgwick, and which forms the basis of all subsequent classifications. The well-known narrow band of Coniston Limestone was shown to form a natural separation between the slates of the second and third divisions. This Coniston-Limestone band was proved by Sedgwick to contain a fauna similar to that of his Bala rocks of North Wales, whilst the true slates of the third division undoubtedly contained, in their higher portions, fossils similar to those of the typical Silurian rocks of the area explored by Sir Roderick Murchison. At this time the beds which form the subject of this communication were not separated off from that division of the Upper Slates to which Prof. Sedgwick, in 1845, applied the term "Coniston Flags;" so that all that was written previous to the period when that separation was effected, concerning the relationship of the Coniston Flags to the Coniston-Limestone series, applies also to the relationship between the latter and the Stockdale Shales. In Professor Sedgwick's writings we find the Coniston Flagstones or Flags at one time connected with the Coniston-Limestone series, at another separated from these and united to the rocks above them; and he finally adopts this arrangement, and, to quote the words used in his 'Letters' to Wordsworth, places the Coniston Flags "at the base of the Upper Silurian series of the Lake District."

The beds now known as the Stockdale Shales were originally distinguished by Professors Harkness and Nicholson in the year 1868, in a paper "On the Coniston Group" (Quart. Journ. Geol. Soc. vol. xxiv. p. 296).

These authors describe the lower portion of the Stockdale Shales under the name of "Graptolitiferous Mudstones," and give a list of fossils found in these beds at Skelgill and in Long Sleddale. They refer to the beds now included in the upper part of the Stock-

dale Shales under the term "Grey Grits." Both these sets of deposits are included as a subdivision of the Coniston Flags, and the Mudstones are considered to rest conformably upon the Coniston Limestone, and are referred by the authors to the Bala.

We append a brief abstract of the views expressed in various papers which have appeared subsequently to the one above referred to, and which treat specially of the Stockdale Shales.

1868. "On the Graptolites of the Coniston Flags," by H. A. Nicholson (Q. J. G. S. vol. xxiv. p. 521).

Alters the term "Graptolitiferous Mudstones" to "Graptolitic Mudstones," and describes many Graptolites from these beds.

1868. 'An Essay on the Geology of Cumberland and Westmoreland,' by H. A. Nicholson.

The Stockdale Shales included as a member of the Coniston Flags. Fossil lists given. Age considered as between that of Bala Limestone and that of Lower Llandovery.

1872. "Migrations of the Graptolites," by H. A. Nicholson (Q. J. G. S. vol. xxviii. p. 217).

Gives list of species from the "Graptolitic Mudstones."

1872. "Memoirs of the Geological Survey." Explanation of Quarter Sheet 98, N.E., by Messrs. W. T. Aveline and T. M^{c}K. Hughes.

First use the term "Stockdale Shales," and separate them from the Coniston Flags: divide them into a lower portion, "Graptolitic Mudstones," and an upper, "Pale Slates." Give the lithological characters of each, and a list of fossils from the "Graptolitic Mudstones" of Holbeck Gill (=Skelgill), near Ambleside. Refer them to Upper Silurian.

1872. "On the Silurian Rocks of the English Lake District," by Prof. H. A. Nicholson (Proc. Geol. Assoc. 1872, p. 105).

Discusses age of "Graptolitic Mudstones"; abandons view that they belong to Coniston Flags, and refers them to Lower Silurian, and considers them conformable with beds above and below.

1872. "On the Continuity and Breaks between the various divisions of the Silurian Strata of the Lake District," by W. T. Aveline (Geol. Mag. vol. ix. p. 441).

Considers slight unconformity to exist between Coniston Limestone and Stockdale Shales: refers latter to Upper Silurian, and correlates them with Tarannon Shales of North Wales.

1875. "On the central group of the Silurian series of the North of England," by H. A. Nicholson and C. Lapworth (Rep. Brit. Assoc. 1875, p. 78).

Use the term "Coniston Mudstone series" for the Stockdale Shales, and suggest the term "Skelgill Beds" for the "Graptolitic Mudstones," and that of "Knock Beds" for the Pale Slates, and correlate the entire "Coniston Mudstone Series" with the Lower and Upper Llandovery and Tarannon Shales of North Wales.

1876. "Absence of Llandovery Rocks in the Lake District," by W. T. Aveline (Geol. Mag. dec. ii. vol. iii. p. 282).

Again correlates Stockdale Shales with Tarannon Shales.

1876. "Llandovery Rocks in the Lake District," by H. Hicks (Geol. Mag. dec. ii. vol. iii. pp. 335 and 429).

Considers Stockdale Shales of Llandovery age.

1876. "On the Vertical Range of the Graptolitic types in Sweden," by G. Linnarsson (Geol. Mag. dec. ii. vol. iii. p. 241).

Correlates Stockdale Shales with Upper Graptolitic Schists of that country.

1876. "Llandovery Rocks in the Lake District," by C. Lapworth (Geol. Mag. dec. ii. vol. iii. p. 447).

Assigns Skelgill beds to Lower Llandovery.

1877. "On the Strata and their Fossil contents between the Borrowdale Series of the North of England and the Coniston Flags," by Profs. R. Harkness and H. A. Nicholson" (Q. J. G. S. xxxiii. p. 461).

Describe "Graptolitic Mudstones" or "Skelgill Beds," and give lists of Graptolites and of more highly organized fossils from these beds; correlate them with highest beds of Bala series or with lower portion of Llandovery group.

Describe "Knock Beds," and incline to regard them as base of (Upper) Silurian.

1878. "Discovery of Silurian Beds in Teesdale," by Messrs. Gunn and Clough (Q. J. G. S. xxxiv. p. 27).

Describe beds at Cronkley Pencil Mill resembling Pale Slates.

1878. "The Moffat Series," by C. Lapworth (Q. J. G. S. xxxiv. p. 240).

Correlates Skelgill beds with Birkhill Shales, which he refers to Lower Llandovery.

1878. "On some well-defined Life-zones in the . . . Lake District," by J. E. Marr (Q. J. G. S. xxxiv. p. 871).

Refers Skelgill beds to May Hill, and supposes unconformity between them and Ashgill Shales.

1879. "On the Geological Distribution of the Rhabdophora," by C. Lapworth (Ann. & Mag. Nat. Hist. ser. 5, vol. iii.).

Assigns a Llandovery May-Hill age to the Skelgill beds; divides them into a lower (*tenuis*) and upper (*argenteus*) zone, and gives lists of fossils from each.

Besides the above, many papers have appeared which contain incidental references to the Stockdale Shales, or which describe fossils contained therein. These will be alluded to in the body of the paper.

§ III. Description of the Typical Sections of Skelgill and Stockdale.

The most convenient course for us to adopt in describing the succession of the different subdivisions of the Stockdale Shales is to commence with an account of the typical sections of the two stages of the series, and afterwards to supplement this by an account of the resemblances and variations exhibited in the other sections.

The typical section of the beds of the lower stage is that displayed

in the course of the stream near Ambleside, which is termed Holbeck Gill on the maps of the Ordnance Survey, but which has been so often alluded to in geological writings under the name of Skelgill (derived from the farm of High Skelgill, situated near its banks), that it would be highly inconvenient to adopt any other name. It is on account of the strong development of the beds of this stage, in this locality, that one of us, in conjunction with Professor Lapworth, has proposed for the beds the title of "Skelgill Beds," a term which we propose to employ here instead of the more ancient term "Graptolitic Mudstones," because there are other Graptolitic beds in the district, and the term "Mudstone" is hardly so applicable to the true Shales in which the Graptolites are found, as to the bluish-grey clayey beds, devoid of stratification, which occur between the different bands of Graptolitic Shale, and which do not contain Graptolites.

The upper stage of the series is well seen in the course of Stockdale Beck, which also contains a fair development of the lower stage, so that the name of this beck is particularly applicable to the whole series. In a tributary of Stockdale, which is called Browgill on the maps of the Ordnance Survey, there is an excellent development of fossiliferous beds of the upper stage, and those beds of this stage which are not seen here are seen in the larger beck close by; so we propose to adopt the section at Browgill, supplemented by that in the adjoining Stockdale stream, as our type section, and, for the sake of uniformity, as well as in order to have the type sections along the main line of outcrop of the Stockdale Shales, to substitute the term "Browgill Beds" for "Knock Beds" in describing this upper stage of the series. We do this with the consent of Professor Lapworth, who, with one of us, originally proposed the term "Knock Beds" for this series. Our classification, then, is as follows:—

Stockdale-Shale series.	Upper	Browgill stage.
	Lower	Skelgill stage.

A. *The Skelgill Beds of Skelgill.*

The stream of Skelgill Beck well deserves to be considered as furnishing the type section of the lower stage of the Stockdale Shales, not only on account of the magnificent section exposed along its banks, but also on account of its accessibility, and the unrivalled views of the Lake-district hills as seen from its neighbourhood. The stream rises in the moorland immediately to the east of Wansfell Pike, and enters Windermere a few yards south of the Low Wood Hotel, after a course of about two miles. For the first half-mile it runs in a shallow valley through volcanic rocks and the beds of the Coniston-Limestone series, and then reaches a bridge over which passes a cart-track from Troutbeck village, known as Hundreds Road. This bridge we may speak of as the Upper Bridge. At this point the stream, which has been flowing due south, assumes a south-westerly direction, and enters a ravine which is in a straight line with a

shallow depression marking the position of the outcrop of the Skelgill Beds, which are concealed for some distance to the north-east of this point. The beds are seen in the stream immediately after turning the corner below the bridge, and a more or less continuous section of the several members of the stage is traceable along the left bank for about half a mile down the stream to a point about 10 chains east of the farm of High Skelgill. The right bank is mainly composed of Ashgill Shales, with a few exceptions to be noted subsequently. At the point near High Skelgill the stream once more turns due south, and soon flows over the beds of the Browgill stage, so that at present our description will be limited to the exposures in that part of the stream which runs between the Upper Bridge and the point at which the stream again turns due south near High Skelgill Farm. Along this portion the direction of the stream is parallel with that of the strike of the beds, which is here nearly due N.E.–S.W., and the beds are dipping at a comparatively low angle, averaging about 35° to the S.E.

Below the Upper Bridge the stream runs for a distance of about 15 chains through a ravine cut in the moorland, and we may speak of this as the "moorland" portion of the gill. From this point until a wall is reached, about 5 chains east of the spot near the farm where the stream once more turns due south, it flows through a wooded ravine, and this we shall refer to as the "wooded" portion of the gill. About 5 chains below the point where the stream enters this wood is a foot-bridge, over which a footpath, slanting obliquely up the steep left bank of the stream, is carried; this is the Lower Bridge. Some 15 chains further down the first important tributary from the north enters the main stream, and a few yards further down a second tributary from the north joins the main beck at the point where the latter quits the wood. The remaining few chains over which the stream preserves its S.W. direction are on swampy ground, with no sections; and at the point where the flow changes to the southward, a third tributary enters the main stream from the north.

After these preliminary remarks, we may proceed to describe the section in greater detail.

The most continuous vertical exposure which is readily accessible is seen at the Lower Bridge, which one of us, in a paper printed in the Society's Journal for 1878, has spoken of as the Lower Footbridge. The section there inserted is, in the main, correct, but some of the thicknesses have to be modified as a result of numerous subsequent measurements (fig. 1).

Aa. Lower Skelgill Beds.

(1) A few yards below the Lower Bridge a cliff, some 10 feet in height, is seen, standing immediately above the stream on the left bank. Here the stream is seen to be flowing over the highest beds of the Ashgill Shales, containing the characteristic Brachiopods of the deposit, and having a discontinuous line of calcareous nodules

at the summit. Immediately above this is a very tough bed, one foot thick, consisting of an impure, compact limestone, containing flocculent dark-grey patches, giving it a mottled appearance, and holding a considerable quantity of iron-pyrites. There are no subsidiary planes of deposition in this bed, which breaks with extreme

Fig. 1.—*Section across Skelgill.* (Scale 15 feet to 1 inch.)

difficulty, with a somewhat hackly fracture. At this point we have obtained no fossils, but a few yards above the Lower Bridge, at a spot presently to be described, there are a fair number of fossils, which are obtainable with difficulty, the most abundant being a new species of *Atrypa*, on which account we propose to term this bed the Zone of *Atrypa flexuosa*.

(2) Immediately over this hard limestone band are bluish-black, rather flaggy and somewhat calcareous shales, resting with perfect

conformity upon the limestone. One foot above the limestone is a permanent divisional plane, which is markedly slickensided, and along which some movement has taken place. A little more than a foot above this is another prominent, slickensided, divisional plane, against which the laminæ are seen to die out at the S.W. end of the cliff, whilst at the N.E. end a little fault-breccia occurs, showing that there has certainly been some disturbance here. About one foot above this is a marked, pale-green band, and above this six feet six inches of blackish shales occur, passing to the top of the cliff, where a great mass of fault-breccia marks the position of a considerable strike-fault. The Graptolites preserved in these black shales, which here have a thickness of at least 9 feet 9 inches, are difficult to extract from this cliff; but fortunately at this point the shales are also developed on the right bank of the stream, where the black calcareous shales are seen dipping immediately at those on the cliff, and an examination of the rocks in the bed of the stream forbids the existence of any fault. The identity of the beds is proved by the fact that the Graptolites, which are beautifully preserved in the shales seen in an excavation in the bank, a few feet above the stream, are identical with those obtainable with some difficulty in the shales of the cliff. These species are:—

Monograptus leptotheca, *Lapw.*
—— Sandersoni, *Lapw.*
—— revolutus, *Kurck.*
—— tenuis, *Portl.*
—— attenuatus, *Hopk.*
Dimorphograptus confertus, *Nich.*
—— elongatus, *Lapw.*
Diplograptus sinuatus, *Nich.*
—— longissimus, *Kurck.*
—— vesiculosus, *Nich.*
Climacograptus normalis, *Lapw.*
—— minutus, *Carr.*

Of these forms the most noticeable are the remarkable *Dimorphograptus confertus*, Nich., which occurs in swarms, especially along one bedding-plane, where it is found to the almost complete exclusion of any other species, and *Monograptus revolutus*, which is also very abundant. One example of *Dimorphograptus elongatus* occurred.

We shall speak of this zone as the *Dimorphograptus-confertus Zone*; and this and the underlying zone, we regard as constituting the *Lower Skelgill Beds*.

It will be convenient to consider the development of these beds in other parts of the gill before proceeding to describe the higher subdivisions.

Although the Lower Bridge crosses the gill in the wooded portion, nevertheless the wood mainly occupies the left bank of the stream until we attain a point a few yards below the Lower Bridge, where the right bank also becomes wooded, to the south-west of a wall which runs down this bank to the top of the small cliff overhanging the stream. Here the fault described as occurring at the top of the small cliff in which the beds of the *Dimorphograptus-confertus Zone* are developed has come down to the stream, and the Ashgill Shales are immediately succeeded by higher beds, which are much crushed

at the base, the Lower Skelgill Beds being entirely faulted out; but some distance below this wall the *Dimorphograptus-confertus* Beds are again exposed on the right bank of the stream, which here forms a dip-slope from which the shales of this zone may be broken off in slabs of considerable size. Most of the fossils obtained at the Lower Bridge are found here, and where the shales are unweathered the Graptolites have been replaced by white calcite, though in the weathered state they occur as yellow-brown impressions, as is the case for the most part with those found at the Lower Bridge. On the opposite side of the stream at this point the section is very similar to that at the Lower Bridge on the same bank, though there is a smaller thickness of shales of the *Dimorphograptus-confertus* Zone below the fault. The portion seen is disturbed, a slight disturbance having probably crushed out a portion of the *Atrypa-flexuosa* Limestone, which is here only three inches thick. Above this we find ten inches of calcareous bluish flags, with the usual Graptolites of the *Dimorphograptus*-zone, above which is a calcareous pyritous band, apparently in the position of the slickensided divisional plane noticed in the section at the Lower Bridge. This band contains badly preserved Graptolites along with numerous Ostracods and small Brachiopods, whose identification it would be too hazardous to attempt. Isolated plates of a species of *Turrilepas* are also tolerably abundant.

Lower down the strike-fault is more pronounced, and where there are exposures the Lower Skelgill Beds are again entirely cut out, until we reach the second tributary from the north, on the west bank of which is seen the *Atrypa-flexuosa* band halfway up in a cliff, separating the *Dimorphograptus-confertus* Beds above, with the usual fossils, from the Ashgill Shales below.

Returning now to the Lower Bridge, and tracing the Lower Skelgill Beds up stream, we find the *Atrypa-flexuosa* Limestone resting on the Ashgill Shales immediately above the bridge; but the beds above it are here covered with talus. A few yards higher up the stream a dip-fault with a downthrow of a few feet to the north runs in a general E.-W. direction, bringing the Ashgill Shales against the *Dimorphograptus-confertus* Beds on the right bank of the stream, and the strike-fault, which has here reached the bed of the stream, has caused the disappearance of a much greater thickness of beds on its north side, so that at the foot of a high precipice, which will be hereafter noticed as containing a magnificent exposure of some of the Middle Skelgill Beds, not only are the *Dimorphograptus-confertus* Beds faulted out, but also the lower part of the Middle Skelgill Beds, which latter rest against the *Atrypa-flexuosa* Bed. This limestone is here seen in the stream, and after being somewhat displaced again by another dip-fault (which runs up a deep gash on the north-east side of the high cliff, in the same way as the first-named dip-fault runs up a similar gash on the south-west side of the cliff), it is well seen resting on the uppermost beds of the Ashgill Shales, at a point where the stream turns a corner and runs down a steep dip-slope. Here the highest Ashgill Shales again contain the calcareous nodules

noticed before, and the *Atrypa-flexuosa* band, which is one foot thick, contains a number of fossils, including:—

Climacograptus normalis, *Lapw.*	Strophomena.
Atrypa flexuosa, n. sp.	Homalonotus?

The breccia of the strike-fault is here seen immediately above the limestone, nor do we meet with any exposure of the *Dimorphograptus-confertus* Beds on the left bank of the stream above this point, the strike-fault usually occurring in the bed of the stream and bringing the Middle Skelgill Beds against the *Atrypa-flexuosa* Zone or even the Ashgill Shales.

At one point however, in the moorland portion of the stream, a very good exposure of the *Dimorphograptus-confertus* Beds occurs on the right bank. This is about a hundred yards below the Upper Bridge. Below the Upper Bridge the stream makes a bend, leaving a promontory mainly composed of the Middle Skelgill Beds in a greatly shattered condition, and at the south-west corner of the promontory the *Dimorphograptus-confertus* Beds are seen dipping so as to pass beneath the Middle Skelgill Beds, though a short interval occurs between them, certainly occupied by the usual strike-fault, the breccia of which is seen in places.

The *Dimorphograptus*-beds consist of blue mudstones, here breaking into rectangular fragments, and resting on the Ashgill Beds, against which they are crushed, as shown by the absence of the *Atrypa-flexuosa* band, and the disturbed character of the *Dimorphograptus*-beds, where brought against the Ashgill Shales. The fossils here are somewhat different from those seen at the Lower Bridge. We have found:—

Monograptus revolutus, *Kurck.*	Dimorphograptus confertus, *Nich.*
—— Sandersoni, *Lapw.*	—— Swanstoni, *Lapw.*
—— attenuatus, *Hopk.*	Diplograptus vesiculosus, *Nich.*
—— tenuis, *Portl.*	—— modestus, *Lapw.* ?

Of these, *Diplograptus vesiculosus*, Nich., *Dimorphograptus Swanstoni*, Lapw., and *Monograptus tenuis*, Portl., are abundant, whilst *Dimorphograptus confertus*, Nich., is rarer. We consider that these beds are somewhat higher in the series than those occurring at the Lower Bridge:—first, because the *D.-confertus* Beds at the Lower Bridge immediately succeed the *Atrypa-flexuosa* Limestone; and secondly, because *Monograptus tenuis* is comparatively abundant in the shales immediately below the strike-fault in the cliff just below the Lower Bridge, whilst it is much rarer lower down the cliff, where *Dimorphograptus confertus*, Nich., becomes so abundant. Nevertheless we are not prepared to divide the *Dimorphograptus-confertus* Zone into a lower band characterized by the abundance of *D. confertus*, Nich., and an upper band characterized by the comparative scarcity of *D. confertus*, Nich., and the abundance of *D. Swanstoni*, Lapw., and of *Diplograptus vesiculosus*, Nich., and *Monograptus tenuis*, Portl., though we think it is highly probable that this might be done.

Before passing on to describe the Middle Skelgill Beds, we may sum up the results we have arrived at:—

(i) The uppermost Ashgill Shales are marked by a band of calcareous nodules. These shales pass up conformably into the overlying beds (Lower Skelgill Beds).

(ii) The Lower Skelgill Beds are divisible into two zones :—

(1) A limestone, one foot in thickness, containing *Atrypa flexuosa* and other fossils : = *Atrypa-flexuosa* Zone.

(2) A set of hard, calcareous shales, of which at least 9 feet 6 inches, are seen, to which we must add three or four feet more if the beds with *Dimorphograptus Swanstoni*, Lapw., are different from those with numerous *D. confertus*, Nich. These shales contain abundance of *Dimorphograptus confertus*, Nich., along with *Monograptus revolutus*, Kurck, *Diplograptus vesiculosus*, Nich. &c. : = *Dimorphograptus-confertus* Zone.

(iii) A strike-fault occurs everywhere in the gill between this zone and the overlying Middle Skelgill Beds, so that the thickness of the *Dimorphograptus-confertus* Beds and of the lowest member of the Middle Skelgill Beds can never be ascertained in this stream.

(iv) The Lower Skelgill Beds, which are harder and more calcareous than the succeeding Graptolitic bands, are always continuous with the underlying Ashgill Shales, and are therefore usually found on the right bank of the stream, whilst the succeeding beds are almost entirely confined to the left bank, as the stream has naturally worked its way along the strike-fault for the greater part of this portion of its course.

A*b*. *Middle Skelgill Beds.*

(1) Starting again at the Lower Bridge, and examining the discontinuous rock-exposures in the wooded bank of the stream above the breccia of the strike-fault (which, it will be remembered, occurred above the *D.-confertus* Beds of the cliff immediately below the bridge, and on the left bank of the stream), we find black shales, with a considerable quantity of pyrites, and containing many Graptolites in high relief. Just above the bridge, a thickness of four feet of these beds used to be visible, below some blue mudstones from which Graptolites are absent. The beds are better displayed in the small cliffs which occur on the left bank of the stream at various points in the wood, commencing about halfway between the Lower Bridge and the first tributary from the north, and continuing to the junction of the main beck with this feeder. The blue mudstones devoid of Graptolites are seen here, and below them, and between them and the strike-fault so frequently alluded to, we get the following section in descending order :—

	ft.	in.	
Black Graptolitic shales	3	6	
Pale green band		¼	
Black Graptolitic shales	1	3	
Non-Graptolitic striped bed		6	
Black Graptolitic shale	2		seen above the fault.
Total	7	3¼	seen.

This is the greatest thickness of these beds which we have measured between the strike-fault and the overlying blue mudstones. In other parts of the stream the strike-fault approaches nearer to the mudstones and, indeed, frequently cuts out these black Graptolitic shales altogether. The passage from the Graptolite-bearing beds into the blue mudstones above is complete. The Graptolites become much scarcer about two inches from the summit of the black beds, and at the same time the blackness of the rock diminishes, until, when the last Graptolites are seen, the rock has assumed a greyish-blue colour, and its hardness has increased considerably.

The group of Graptolitic shales we are now considering may be seen at several points in the wood above the bridge, and in most cases the passage can be traced into the blue mudstones above. At the great cliff just above the foot-bridge the strike-fault has cut out these beds and brought the overlying blue mudstones against the *Atrypa-flexuosa* Bed, but on the other side of the dip-fault which bounds the N.E. side of this cliff the shales are again seen, though greatly crushed at the base. Many fossils, in an admirable state, may be obtained near an adit which has been driven into the shales, a little below the top of the wood; and at the end of the wood, where we emerge upon the moorland, the strike-fault is seen on the left bank of the stream, where the shales are crushed into a mass of black mud with ferruginous stains, immediately above which the blue mudstones are seen in the cliff. Higher up the stream, the Graptolitic shales below these mudstones are cut out, except at the promontory on the right bank of the stream just below the Upper Bridge. Here the shales are seen in a very crushed state on the north-east side of the promontory, succeeded, as usual, by the blue mudstones.

The group of shales we have above described is distinguished from those we have already considered, and from others which yet remain to be described, by lithological and palæontological characters.

The beds are extremely dark, generally almost or quite black, and though earthy are yet hard, and break into rather massive pieces. They are more cleaved than the shales below, and as the Graptolites are chiefly found along bedding-planes separated from one another by an inch or two of rock in which fossils are scarce, they do not break into quite such thin slabs as do the shales of the *D.-confertus Zone*. Several narrow lines of pale green mudstone occur here and there, and in these Graptolites are very seldom found, though they are not entirely absent. Pyrites occurs abundantly both in nodules and in irregular patches along the bedding-planes, and, as a result, the joints and cleavage-planes are usually stained a very deep brown.

The fossils usually occur in a state of high relief, and are mostly pyritous and of a golden colour, though sometimes they are graphitic and silvery when first obtained. Most of the following fossils are readily found wherever these shales occur in the stream :—

Monograptus fimbriatus, *Nich.*
—— gregarius, *Lapw.*
—— tenuis, *Portl.*
—— attenuatus, *Hopk.*
—— Sandersoni, *Lapw.*
—— leptotheca, *Lapw.*
—— triangulatus, *Harkn.*
—— cyphus, *Lapw.*
Rastrites peregrinus, *Barr.*
Diplograptus tamariscus, *Nich.*
Diplograptus sinuatus, *Nich.*
—— Hughesii, *Nich.*
—— modestus, *Lapw.* ?
—— vesiculosus, *Nich.*
Petalograptus ovatus, *Barr.*
—— ovato-elongatus, *Kurck.*
Climacograptus normalis, *Lapw.*
Dawsonia campanulata, *Nich.*
Discinocaris, n. sp.
Orthoceras araneosum, *Barr.*

The above is a complete list of all the fossils found in these shales in the gill. The first-named occurs everywhere in the zone in great abundance, and usually in a beautiful state of preservation, and we have met with it in no other beds either above or beneath. We shall therefore speak of these shales as composing the Zone of *Monograptus fimbriatus*.

Monograptus gregarius, Lapw., *Rastrites peregrinus*, Barr., *Petalograptus ovatus*, Barr., and *P. ovato-elongatus*, Kurck, are all abundant, and we frequently find beds covered with a confused mass of *Monograptus attenuatus*, Hopk. *Dawsonia campanulata*, Nich., is often found in groups. We have only seen one or two doubtful examples of *Diplograptus vesiculosus*, Nich. It is to be noted that the genus *Rastrites*, which appears so abundantly in this horizon, has never been found by us in any of the Lower Skelgill Beds.

(2) Above the Zone of *Monograptus fimbriatus* we find a more or less continuous section of the Middle Skelgill Beds all the way between the two bridges; and the observations made at the Lower Bridge may be frequently checked by an examination elsewhere. The sections below the Lower Bridge are less continuous, but here and there high cliffs occur, showing a good development of the various subdivisions. The blue mudstones succeeding the *fimbriatus*-zone are seen at the bottom of the path which crosses the Lower Bridge. They are five feet in thickness, and pass downward in the manner described into the *M.-fimbriatus* beds. At the summit a similar passage is traceable into a thin black Graptolitic band.

The blue mudstones are hard, somewhat cleaved, grey-blue beds, with prominent bedding-planes some distance apart. The rock is somewhat calcareous, but the carbonate of lime has been mostly collected into a series of extremely tough nodules, which have weathered out along the cliff-faces, and show as a series of rust-stained holes. The following measurements were taken at the Lower Bridge, and show the variations in the band, the section being a descending one:—

	ft.	in.
Blue mudstones passing into Graptolite-shales above ...	1	0
Nodule-band.		
Blue mudstones		10
Nodule-band.		
Blue mudstones	1	0
Nodule-band.		
Blue mudstones		7
Nodule-band.		
Blue mudstones		7
White streak.		
Blue mudstones, passing into *M.-fimbriatus* beds	1	0
Total	5	0

The nodules are again well exhibited in the cliff at the bottom of the moorland portion of the gill, just before the stream enters the wood, and in many places between this and the Upper Bridge. At one point, however, where the cliff attains a great height, and has a concave curve produced by a loop of the stream, these beds are faulted out, and a higher set of mudstones is brought down against the strike-fault, which here runs in the bed of the stream.

The fossils of the mudstones which we have been describing are procurable with some difficulty, owing to the hardness of the rock. They are not often found on the bedding-planes, which usually present wrinkled surfaces, so that the rock must be broken across in order to obtain the well-preserved fossils. We have found:—

Encrinurus punctatus, *Wahl.*, var. arenaceus, *Salt.*	Leptæna quinquecostata, *M'Coy.*
Acidaspis.	Orthoceras araneosum, *Barr.*

The *Encrinurus* is a tolerably common fossil, and we have not hitherto met with it in any of the other deposits in this gill, so we use it to mark this zone, which we consequently name the *Zone of Encrinurus punctatus*, Wahl.

(3) Above this zone comes a band of small thickness, but of great interest, owing to the varied assortment of fossils which it contains. It occurs right in the centre of the Middle Skelgill beds, and is succeeded by mudstones of a similar lithological character to those which lie below it, and passes up into them in the same manner. The lower portion of these upper mudstones, similarly to the upper portion of the lower group, consists of light-coloured, shaly layers, and between these two we find eight inches of extremely black shales, somewhat similar to those of the *M.-fimbriatus* Zone, but even harder, and containing Graptolites in an exquisite state of relief. About three inches from the summit of this bed is a pale-green streak in which Graptolites are extremely rare, and which is remarkable for its extraordinary persistence. The bed is seen by the path which crosses the Lower Bridge, and may be traced passing along the face of the cliff to the dip-fault which occurs a few yards above the bridge. It is here thrown down, and occurs in the great precipice between the two dip-faults, at a height of a foot or two above the stream. It is marked all the way from the path to the north-east end of this cliff by a furrow caused by our removal of the shales, so that it is now extremely difficult to get satisfactory specimens at this spot. The same bed may be found at one or two points below the Lower Bridge, but in many places, both here and above the bridge, the deposit is inaccessible. Along a great part of the cliff below the Upper Bridge the band is found to be crushed out, and the mudstones above are brought into contact with those below; but on tracing the line of junction the thin band gradually appears, at first much crushed, but further away from the point of maximum disturbance it is in its normal condition. At the point of maximum throw of the principal strike-fault of the stream the beds are absent

from the base to this zone inclusive, and the succeeding mudstone bed is brought against the Ashgill Shales.

The fossils enumerated in the ensuing list have been discovered by us in this black band:—

Monograptus argenteus, *Nich.*
—— gregarius, *Lapw.*
—— leptotheca, *Lapw.*
—— Nicoli, *Harkn.*
—— Clingani, *Carr.*
—— crenularis, *Lapw.*
—— cyphus, *Lapw.*
—— convolutus, *His.*
—— involutus, *Lapw.*
—— attenuatus, *Hopk.*
—— argutus, *Lapw.*
—— Hisingeri, *Carr.*
—— tenuis, *Portl.*
Rastrites peregrinus, *Barr.*
Rastrites hybridus, *Lapw.*
—— urceolus, *Richter.*
—— gemmatus, *Barr.*
Diplograptus sinuatus, *Nich.*
—— tamariscus, *Nich.*
—— Hughesii, *Nich.*
—— modestus, *Lapw.*?
Petalograptus ovatus, *Barr.*
Climacograptus normalis, *Lapw.*
Discinocaris Browniana, *Woodw.*
—— gigas, *Woodw.*
Dawsonia campanulata, *Nich.*
Orthoceras araneosum, *Barr.*

The beautiful *M. argenteus*, Nich., which used to be readily procurable from this band, appears to be entirely confined to it, and although the bed is so thin, its fauna is so rich, and the bed such a remarkable one in every particular, that we consider it worthy of being ranked as a distinct zone, which we term the *Zone of Monograptus argenteus*.

(4) Once more we return to the Lower Bridge, and proceed to examine there the mudstones into which the *M.-argenteus* Zone passes upward.

What we have said of the lithological characters of the *Encrinurus-punctatus* Zone is applicable here, except that the calcareous nodules, instead of being spread at nearly equal distances throughout the deposit, are chiefly collected towards its centre. Otherwise, we meet with the same blue mudstones, with bedding-planes tolerably far apart, and the intervening rock breaking with the same difficulty as that of the *Encrinurus*-zone. The calcareous nodules weather out leaving a brown or chocolate-coloured earth, which is also frequently found along the bedding-planes. The following details of these mudstones, given in descending order, and measured at this foot-bridge, are generally applicable to the horizon at other parts of the gill:—

	ft.	in.
Blue mudstones (passing up into Graptolitic shales) ...	4	0
Nodule-band.		
Blue mudstones		6
Nodule-band.		
Blue mudstones		6
Nodule-band.		
Blue mudstones		10
Nodule-band.		
Blue mudstones		3
Nodule-band.		
Blue mudstones	6	0
Total.....	12	1

This is one of the most prominent bands in the gill, as the lines of nodules present a very striking appearance, and as the whole deposit is traversed by a series of strike-joints, along which it breaks off in massive blocks, sometimes four or five feet in length each way; the overlying shales usually present a projecting cornice of jagged appearance above the smooth face of the portion of the cliff which is composed of these mudstones. For these reasons, there is not the slightest difficulty in tracing this band wherever exposed, and there are few places where this hard blocky deposit is concealed by detritus. Where the band comes down to the stream, at the point of maximum disturbance produced by the strike-fault, namely in the very high precipice in the moorland part of the gill, a number of flat elliptical concretions, with a reticulated surface and a black earthy appearance, were found by us in it. These concretions are apparently formed of oxide of manganese, and they probably occur in other parts of the gill, though we have not come across them.

The fossils of this band are admirably preserved, like those of the *Encrinurus*-zone. They are:—

Favosites mullochensis, *Nich. & Eth., jun.*
Phacops elegans, *Bœck & Sars.*
—— ——, var. glaber.
Cheirurus bimucronatus, *Murch.*, var. acanthodes, var. nov.
Cheirurus moroides, n. sp.
Harpes angustus, n. sp.
—— judex, n. sp.
Calymene Blumenbachii, *Brongn.*?
Whitfieldia tumida, *Dalm.*?

The new variety of *Phacops* is the most prominent fossil, and, although not confined to this band, occurs more abundantly here than elsewhere; hence the name we have adopted for this band, viz. the *Zone of Phacops glaber*.

(5) The Graptolitic shales which have been alluded to as forming a cornice above the *P.-glaber* zone in the precipices are seen about halfway up the path which crosses the Lower Bridge, where the usual gradual passage from the mudstones to the Graptolite-bearing shales may be observed. This passage always takes place in the vertical distance of two or three inches, and is due to the gradual development of lamination-planes in the mudstones, which at the same time begin to contain a few Graptolites, assume a darker hue, and are not calcareous. These Graptolitic shales above the *glaber*-zone are very finely laminated, so that they break into thin pieces, thus differing from the mudstones of the *M.-argenteus* and *M.-fimbriatus* zones and of the Lower Skelgill Beds. When much jointed and cleaved, they break up into small rectangular pieces, but when the divisional planes produced subsequently to deposition are less marked, they afford tolerably large but thin slabs. The shales are also less dark than those of the underlying Graptolitic zones, the usual tint being a somewhat dark greyish blue instead of black, though here and there black shales do occur. One of the most noticeable features is the light olive-brown staining of the joint surfaces; by this peculiarity, and by their fissile character, they are

readily distinguishable from any of the preceding Graptolite-zones, even at a distance of some yards.

The entire thickness of this subdivision is seven feet nine inches, and the subjoined details are given, as usual, in descending order:—

	ft.	in.
Richly Graptolitic black shales, passing into mudstones above...		4
Blue mudstones, with few Graptolites		11
Graptolitic shales	3	8
Green mudstones	1	6
Graptolitic shales		2
Green streak.		
Graptolitic shales, passing into *glaber*-zone below	1	2
Total	7	9

The lowest part, one foot four inches in thickness, lying below the green mudstones, is distinguished by the great abundance of *Diplograptus tamariscus*, Nich., preserved in a state of semi-relief. As this species is tolerably abundant elsewhere, including the upper part of the zone under consideration, we do not intend to separate this lowest portion as a distinct subzone, especially as all the fossils found in it occur in the rest of the zone; but we call attention to it, as a similar abundance of *D. tamariscus* is found on the same horizon in other sections.

As the shales of this zone are easily distinguished in other parts of the gill, and present no particular variations, we need not give a detailed description. Most of our fossils have been obtained from the immediate neighbourhood of the Lower Bridge, from the angle of the stream just above the high precipice a few yards above this bridge, and from the bank just N.E. of the high precipice in the moorland portion of the stream. These fossils are:—

Monograptus convolutus, *His.*
—— gregarius, *Lapw.*
—— Clingani, *Carr.*
—— crenularis, *Lapw.*
—— communis, *Lapw.*
—— Nicoli, *Harkn.*
—— attenuatus, *Hopk.*
—— argutus, *Lapw.*
—— cyphus, *Lapw.*
—— involutus, *Lapw.*
Rastrites hybridus, *Lapw.*
—— peregrinus, *Barr.*
Rastrites urceolus, *Richter.*
—— gemmatus, *Barr.*
Petalograptus cometa, *Gein.*
—— folium, *His.*
—— ovatus, *Barr.*
Retiolites perlatus, *Nich.*
Diplograptus Hughesii, *Nich.*
—— tamariscus, *Nich.*
—— modestus, *Lapw.*
Climacograptus normalis, *Lapw.*
Dawsonia campanulata, *Nich.*
Leptæna quinquecostata, *M'Coy.*

Of these *M. convolutus*, His., is the most prominent form. It does occur in the *M.-argenteus* zone in considerable abundance, but it is found here in a beautiful state of preservation and in great abundance; only one specimen of *P. cometa* has been found in this gill. We name this zone the *Zone of Monograptus convolutus.*

(6) The succeeding blue mudstones, which we take as marking the summit of the Middle Skelgill Beds, are seen on the footpath at the Lower Bridge, near its summit. They are four feet in thickness, and similar in lithological characters to the mudstones of the *Phacops-glaber* zone, but do not contain any band of calcareous nodules.

They are seen in many parts of the gill, immediately succeeding the shales of the *M.-convolutus* zone. Fossils are rare, and the mudstones are of little interest. They have yielded :—

Phyllopod spine.
Whitfieldia tumida, *Dalm.* ?
Leptæna quinquecostata, *M'Coy.*

We shall speak of this band as the *Barren Band.*

To sum up the results obtained in our examination of the Middle Skelgill beds :—

(i) The base is nowhere seen, owing to the strike-fault.

(ii) The beds form the chief portion of the great cliff-section which occurs on the left bank of the gill from the Upper Bridge to the bottom of the wood.

(iii) The beds are divisible into three zones of Graptolitic shales, each topped by a zone of blue mudstones :—

(1) A zone of black, pyritous, earthy, somewhat hard mudstones, at least 7 feet thick, with *Monograptus fimbriatus*, Nich., *M. gregarius*, Lapw., *Rastrites peregrinus*, Barr., *Petalograptus ovato-elongatus*, Kurck, and *Dawsonia campanulata*, Nich., &c. : = *Monograptus-fimbriatus* zone.

(2) A zone of hard, blue, bedded mudstones, 5 feet thick, with bands of calcareous nodules, containing *Encrinurus punctatus*, Wahl., &c. : = *Encrinurus-punctatus* zone.

(3) A thin band of black mudstones, only 8 inches, with *Monograptus argenteus*, Nich., *M. gregarius*, Lapw., and a host of other fossils : = *Monograptus-argenteus* zone.

(4.) A zone of hard, blue, bedded mudstones, 12 feet in thickness, with many calcareous nodules towards the centre, and containing many Trilobites, including *Phacops elegans*, var. nov. *glaber* : = *Phacops-glaber* zone.

(5) A thick zone of laminated, dark, greyish-blue Graptolitic shales, with olive-brown stains on the joint-faces, having several green streaks throughout and thick deposits of mudstones near the top and base, the whole attaining a thickness of 7 feet 9 inches, and containing *Monograptus convolutus*, His., *Monograptus gregarius*, Lapw., and many other Graptolites : = *Monograptus-convolutus* zone.

(6) A zone of blue mudstones, 4 feet thick, and containing few fossils : = *Barren Band.*

Ac. *Upper Skelgill Beds.*

(1) The Graptolite-shales which succeed the highest beds of the Middle Skelgill group are only one foot thick. They consist of very fissile laminated shales, sometimes black and very ferruginous, and at other times of a lighter colour. They are seen near the Lower Bridge near the summit of the footpath, where they contain a considerable number of fossils. Other and more highly fossiliferous exposures of this band occur at several points above the Lower Bridge, on the moorland portion of the stream. The fossils serve to connect them with a succeeding band of Graptolitic shales, and they themselves contain no characteristic form. Their fossils are :—

Monograptus Clingani, *Carr.*
—— gregarius, *Lapw.*
—— Nicoli, *Harkn.*
—— crenularis, *Lapw.*
—— spinigerus, *Nich.*
—— distans, *Portl.*
—— jaculum, *Lapw.*
Rastrites urceolus, *Richter.*
—— hybridus, *Lapw.*
Diplograptus tamariscus, *Nich.*
—— sinuatus, *Nich.*
Petalograptus ovatus, *Barr.*
—— folium, *His.*
Climacograptus normalis, *Lapw.*
Favosites mullochensis, *Nich. & Eth., jun.*
Peltocaris aptychoides, *Salt.*
Aptychopsis Lapworthi, *Woodw.*

From the abundance of *Monograptus Clingani*, Carr., which usually occurs in an immature condition, this band may be termed the *M.-Clingani Band*; it is not worthy to rank as a distinct zone. Only one specimen of *Monograptus gregarius* has been hitherto discovered in it.

(2) The *Clingani*-band passes up in the usual manner into yet another band of blue mudstones, four feet six inches thick, and containing a line of calcareous nodules close to the summit, and another about two thirds of the way up. This is clearly seen on the path at the Lower Bridge, and at many points higher up the stream. Fossils are tolerably abundant, especially between the two lines of calcareous nodules. We have collected:—

Ampyx aloniensis, n. sp.
Harpes angustus, n. sp.
—— judex, n. sp.
Proëtus brachypygus, n. sp.
Phacops elegans, var. glaber.
Cheirurus bimucronatus, *Murch.*, var. acanthodes.

From the occurrence upon this horizon only, and in tolerable abundance, of the very interesting form of *Ampyx*, we name this the *Zone of Ampyx aloniensis.*

(3) The *Ampyx*-zone passes up into an extremely well-marked zone of Graptolitic shales, 3 feet 6 inches in thickness. These beds consist of alternating thin laminæ of black, grey, dirty white, buff, orange, and green shales, with some coarser bands, the surface of which is marked by lozenge-shaped reticulations; they are well seen on the path at the Lower Bridge, and at one or two places along the cliff at the moorland portion of the stream, especially in the bend, opposite the north-eastern end of the promontory, just below the Upper Bridge. They swarm with Graptolites, and we have collected from them:—

Monograptus spinigerus, *Nich.*
—— discretus, *Nich.*
—— jaculum, *Lapw.*
—— distans, *Portl.*
—— leptotheca, *Lapw.*
Petalograptus palmeus, *Barr.*
Diplograptus tamariscus, *Nich.*
—— Hughesii, *Nich.*
—— modestus, *Lapw.*
Climacograptus normalis, *Lapw.*
Orthoceras araneosum, *Barr.*

Monograptus spinigerus, Nich., is very abundant throughout, and occurs in vast abundance in the upper portion of the zone, whilst *Monograptus discretus*, Nich., thickly covers whole slabs of the lower portion of the deposit. There is no doubt that the only suitable name for this band is the *Zone of Monograptus spinigerus.*

(4) The *M.-spinigerus* zone is seen to pass up into the highest beds

of the Upper Skelgill group exposed at the Lower Bridge. We find here 10 feet of blue mudstones, in which we have obtained at this point only a few badly preserved Ostracods. The Browgill Beds occur on the moorland at the Lower Bridge, just above these mudstones, but the actual junction is not seen. The junction is observable, however, at two or three points along the moorland portion of the gill, and the beds are seen to pass with considerable rapidity into the Browgill Beds. Their thickness there is also 10 feet, so that it is evident that the whole thickness is seen at the Lower Bridge. We have searched in vain for other fossils, but found none in this section; but as a remarkable *Acidaspis* occurs upon this horizon in another locality, we term these beds the *Zone of Acidaspis erinaceus*.

To sum up the results obtained from an examination of the Upper Skelgill Beds :—

(i) They are conformable to the Middle Skelgill Beds below, and pass up into the Browgill Beds above without the intervention of any Graptolitic shales.

(ii) They are divisible into two Graptolitic bands, each succeeded by a band of blue mudstones, viz. :—

(1) A band of black and blue thinly laminated shales, one foot thick, with abundance of *Monograptus Clingani*, Carr.: = *M.-Clingani Band.*

(2) A deposit of blue mudstones, 4 feet 6 inches thick, with many Trilobites, including *Ampyx aloniensis*, n. sp.: = *Ampyx-aloniensis Zone.*

(3) A set of Graptolitic shales of various colours from black to deep orange, 3 feet 6 inches thick, and from the abundance of *Monograptus spinigerus*, Nich., therein, termed the *Zone of Monograptus spinigerus.*

(4) A thick group of bedded blue mudstones (10 feet thick) containing few fossils, and passing up into the Browgill Beds above: = *Acidaspis-erinaceus Zone.*

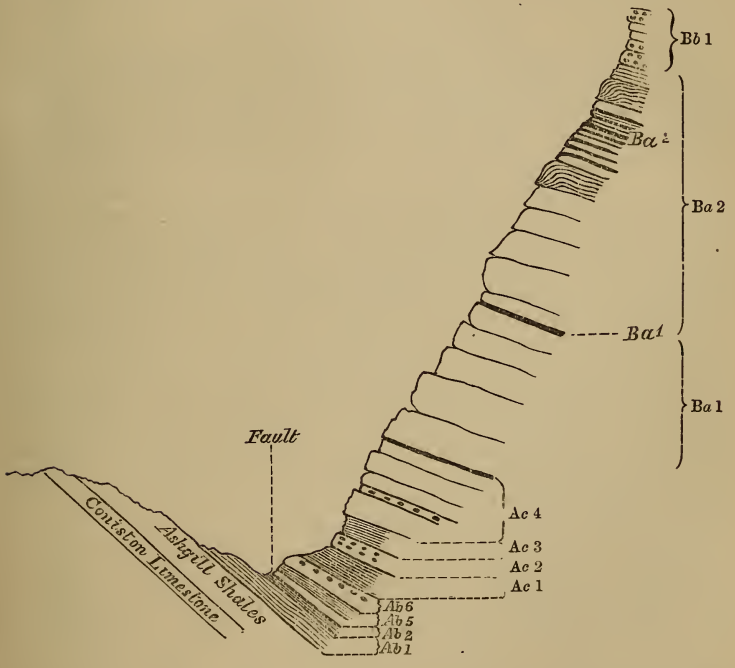
The section (fig. 1, p. 661) shows the succession of the Skelgill Beds at Skelgill, and may be taken as representing the section at the Lower Bridge, some feet being added to the top of the *D.-confertus* zone and to the base of the *M.-fimbriatus* zone to show the maximum thicknesses of these beds, as far as seen in the gill.

B. *The Browgill Beds of Browgill and Stockdale.*

Some ten miles north of Kendal the river flowing from the north through the little valley of Stockdale joins the main valley of Long Sleddale on the east side of the latter. About fifteen chains above the junction of the two streams, the cluster of houses forming the little hamlet of Stockdale is grouped on the right bank of the Stockdale Beck. Close to the stream, and on its north bank, a quarry is excavated in the Lower Coniston (Brathay) Flags, close to the base of the latter, which here as elsewhere contains Graptolites in an excellent state of preservation. Among these are *Monograptus priodon*, Bronn, *M. vomerinus*, Nich., *Cyrtograptus*

Murchisomi, Carr., and *Retiolites Geinitzianus*, Barr. Above this the stream-course is cut for a distance of two chains through the Browgill Beds, and as the passage of these into the Skelgill Beds below is seen beneath a small cascade, the whole of the Browgill Beds are developed in this section, and a nearly continuous section is displayed, the beds dipping quite regularly to the S.S.E. at an angle of about 60°. Just above the cascade which falls over the Coniston Limestone, a tributary enters Stockdale Beck from the north-east; this is Browgill, and the same stream is referred to by Professor Sedgwick under the name of Iron Crow Gill, and by Profs. Harkness and Nicholson under that of Arncoside Beck. The lowest twenty chains of the gill are hollowed in the beds of the Coniston-Limestone series; but at a point a short distance above the 1000-foot contour-line a fault runs diagonally across the stream with a downthrow to the east, which brings the Stockdale Shales against the

Fig. 2.—*Section at "Rake," Browgill.* (Scale 24 feet to 1 inch.)



Coniston-Limestone Series, and the former beds are traceable for some distance up the stream, which here runs along the strike. As at Skelgill, the Coniston-Limestone Series is seen on the north-west bank, which is a dip-slope, and a steep scarp sometimes rising into precipitous cliffs forms the south-east (left) bank. The lower portion of this is occupied by the Skelgill Beds, whilst the upper portion

shows the green grits and shales of the Browgill Beds. The cliff attains its maximum height near the point where the 1250 feet contour-line crosses the stream, and here a cleft occurs in the cliff which is spoken of in the dialect of the country as a "rake"*. We shall speak of this cleft as "The Rake." In its walls there is an admirable exposure of the lower part of the Browgill Beds, which are slightly displaced by a small fault which has determined the formation of the rake.

The section seen in this "rake" is represented in figure 2, where the slope of the cliff is exaggerated in order to save space. The bed Ac 4, which corresponds with the *Acidaspis-erinaceus* zone of Skelgill as will be hereafter shown, is the highest band of the Skelgill Beds. This passes up in the same way as at Skelgill into the pale-green beds of the Browgill group, without the intervention of Graptolitic shales. Two distinct zones of Graptolitic shales occur in the cliff, and it will be convenient to connect with each of them the mass of non-Graptolitic green beds which occurs beneath them.

Ba. *Lower Browgill Beds.*

Ba 1. The pale shales passing into the blue mudstones of the uppermost Skelgill Beds are 21 feet in thickness without the intervention of any black shales in which we have found Graptolites. There is a thin band (under an inch in thickness) at a height of 11 feet 6 inches above the top of Ac 4, but we found no Graptolites therein. The shales are pale green, slightly gritty in places, and well laminated. They frequently contain cubic crystals of iron-pyrites, and dendritic efflorescences of oxide of manganese, and are quite similar to the bulk of the Browgill Beds, which present a great uniformity of character wherever developed. 21 feet above the uppermost Skelgill Beds occurs a thin black band, Ba 1′, weathering to a buff-yellow colour, and crowded along one bedding-plane with tolerably large specimens of *Monograptus turriculatus*, Barr., which are seen as dark-brown stains upon the rock, but are sufficiently well preserved to show the long spines of the cells in many specimens. The only other Graptolite found here is *Monograptus rectus*, Lapw. From the great abundance of *Monograptus turriculatus*, we shall speak of this band with its underlying 21 feet of pale shales as the *Zone of Monograptus turriculatus*, Barr.

Ba 2. Above this Graptolitic band is another mass of pale shales similar in every respect to those of the *turriculatus*-zone. They are disturbed at one point by a small monoclinal fold; but this seems to be unaccompanied by any fracture, so that no shales are apparently faulted out here, and there is a thickness of 19 feet between the black band of the *M.-turriculatus* zone and the group of Graptolitic shales about to be described.

These shales, Ba 2′, consist of olive-green and grey shales, with a

* A "rake" is, on a small scale, the same as a "couloir," and is often formed along a prominent joint-plane or line of fault, or by the weathering-out of a dyke.

number of interstratified greyish-black Graptolitic shales, the whole attaining a thickness of about 15 feet. There are two important Graptolitic bands 2 feet 8 inches apart, and each about 3 inches thick, and a number of minor ones. Many of the species are limited to one or two bands; but it would be difficult to subdivide this group, though it may be noted that *Retiolites Geinitzianus* occurs chiefly in the higher bands. The Graptolitic beds are usually weathered to a buff colour, on which, as in the *M.-turriculatus* zone, the Graptolites occur as brown stains. The fossils are:—

Monograptus crispus, *Lapw.*
—— exiguus, *Nich.*
—— pandus, *Lapw.*
—— discus, *Törnq.*
—— griestonensis, *Nicol.*
Monograptus Hisingeri, *Carr.*
Cyrtograptus Grayæ, *Lapw.*
—— ? spiralis, *Gein.*
Petalograptus palmeus, *Barr.*
Retiolites Geinitzianus, *Barr.*

The four species at the top of the list and the *Retiolites* are extremely abundant. For a long time we were disposed to adopt *M. exiguus*, Nich., as the type-fossil of the zone; but as *M. crispus*, Lapw., appears to be more abundant, we have decided to speak of it as the *Zone of Monograptus crispus*, including with it the 19 feet of pale shales which occur below it, and also the succeeding 10 feet of pale shales devoid of Graptolites which occur between these black shales and the band next to be described. These pale shales contain another monoclinal fold, also apparently unaccompanied by any fault.

B*b*. *Upper Browgill Beds.*

The deposit which we take as the base of the Upper Browgill Beds occurs at the extreme summit of the rake, and above it the moorland is reached with few exposures; but the deficiency of sections can be easily made up by an examination of the beds of the main stream of Stockdale.

The base of these Upper Beds, B*b* 1, consists of a calcareous development of the pale shales seven feet six inches in thickness. We find a lower blue calcareous band with weathered calcareous nodules like those of the *glaber*- and *punctatus*-zones of Skelgill, 2 feet 6 inches thick, separated from an upper band of similar rock, one foot thick, by about four feet of pale shales. We have discovered no fossils in these beds, and indeed, with the exception of a few undeterminable Brachiopods, have obtained no fossils in any locality from the Upper Browgill Beds, though we have searched for them carefully. We feel convinced, however, that some will eventually be found. Before quitting this section it may be noted that we have measured 65 feet of shales and subordinate grits belonging to the Lower Browgill Beds.

Returning to the Stockdale Beck, we can complete the section, which, indeed, is here so much more perfect than that of Browgill that we should certainly have adopted the name Stockdale Shales for the upper group, if it had not been previously used for the whole series. The two zones we have described as forming the Lower Browgill Beds of the rake are also seen in the main beck, where the Graptolitic shales

are unweathered and of a greyish black. It is more difficult to obtain exact measurements in this stream than in the cliffs of the rake, but the thickness given above seems to hold good here also. The calcareous band which we have taken as marking the base of the Upper Browgill Beds is seen in the stream about halfway between the cascade over the Coniston Limestone and the quarry in the Coniston Flags by the stream, north of the hamlet. Above it is a thickness of pale green and reddish-purple grits and shales, passing gradually up by the intercalation of grey bands into the blue-grey Coniston Flags. An approximate measurement shows the occurrence of about sixty feet of these shales between the calcareous band and the base of the Coniston Flags, which gives a thickness of about 130 feet for the whole of the Browgill Beds in this locality.

The chief features which distinguish the Upper Browgill Beds from the Lower ones are:—

(i) The absence of Graptolitic shales;
(ii) The occurrence of more massive grits;
(iii) The reddish-purple colour of some of the beds.

The latter distinction appears to be due to the staining of the beds subsequently to deposition, and it is therefore of little value for classificatory purposes. In some sections along the outcrop of the Stockdale Shales the staining is absent; in other places it penetrates even to the Lower Browgill Beds, and usually takes place among the softer and more shaly deposits. The colouring material seems, however, to have been introduced from above, so that when staining does occur, it affects the Upper Browgill Beds far more than the Lower Beds, which are, indeed, usually entirely unaffected by it.

To sum up the results of the examination of this section:—

B*a*. The Lower Browgill Beds are divisible into:—

B*a* 1. Twenty-one feet of pale shale with a band, one inch in thickness at the summit, marked by the occurrence of *M. turriculatus*, Barr.: =*Zone of M. turriculatus.*

B*a* 2. A set of pale shales 15 feet thick with many Graptolitic bands, having 19 feet of pale shales below and 10 above, total 44 feet, containing *Monograptus crispus*, Lapw., *M. exiguus*, Nich., &c., in abundance: =*Zone of M. crispus.*

B*b*. The Upper Browgill Beds are divisible into:—

B*b* 1. A mass of calcareous blue mudstones with some paler beds, marked by the occurrence of calcareous nodules, and 7 feet 6 inches thick.

B*b* 2. A series of pale green and reddish-purple shales with massive grit beds, the whole attaining a thickness of about 60 feet.

It will be noticed that the calcareous band occurs about the centre of the Browgill Beds, and therefore forms a convenient line of division between the Lower and Upper Beds.

It should be mentioned that the Graptolites of the Browgill Beds of Stockdale and of Browgill are very rarely preserved in relief, and this is true of the Graptolites of the same beds in all parts of the district.

§ IV. Description of Confirmatory Sections.

In confirming the observations made upon the Skelgill Beds of Skelgill and the Browgill Beds of Browgill, by an examination of other sections, we propose first to describe the sections along the main line of outcrop of the Stockdale Shales, beginning at the E.N.E. end and proceeding to the W.S.W., and afterwards to allude to those in the outlying districts.

Although the outcrop of the Stockdale Shales is parallel with that of the Coniston-Limestone series, the latter are seen further eastward than the former. At Shap Wells the Coniston-Limestone series comes out from under the Carboniferous beds in Blea Gill, and the first beds seen above it are in Wasdale Beck, and belong to the Lower Coniston Flags, here considerably altered by the Shap granite, but nevertheless containing the usual vomerine Graptolites. Between these beds there is perhaps room for the Stockdale Shales; but as the highest beds of the Coniston-Limestone series seen in Blea Beck are by no means its uppermost beds, there is almost certainly a strike-fault here, and the Stockdale Shales may be wholly or in part faulted out. As the ground is drift-covered here, and for many miles further east, the presence or absence of the Stockdale Shales cannot be determined. The first satisfactory section of the Stockdale Shales which we have discovered is that seen in Browgill, of which a portion has been already described, and it remains for us therefore to complete the description by the addition of the details of the Skelgill Beds of this beck.

Browgill.

Referring to the section across the beck in fig. 2, it will be seen that an important strike-fault occurs a little above the stream at the rake. This is traceable all along the outcrop of the beds in Browgill, as well as in Stockdale Beck, and separates the Middle Skelgill from the Lower Skelgill Beds, or (in Stockdale Beck) cuts the Lower Beds out altogether. The dip of the beds is different on opposites sides of the fault, being at a much higher angle (about 60°) on the north-west bank of the stream than on the south-east, where it is usually below 30°. The steep dip-slope of the north-west bank is occupied by ordinary Coniston Limestone where it joins the moorland above, and the parts nearer the stream show a development of the Ashgill Shales. These seem to pass up with perfect conformity into the lowest beds of the Skelgill group, which are different from those of the Skelgill Beck.

A*a* 1. We find about 2 feet 6 inches of mottled, light-grey, flaggy, pyritous shale, somewhat calcareous in places, forming the right bank of the stream a little above water-level, and occurring in the bed of the stream itself. Graptolites are not uncommon in it, but we have only succeeded in finding two species, both of which are fairly abundant; they are:—

Diplograptus acuminatus, *Nich.* | Climacograptus normalis, *Lapw.*

There is no doubt, both from the position of this bed and its resemblance to the calcareous *Atrypa-flexuosa* band of Skelgill, that this deposit represents that zone, in which, it will be remembered, *Climacograptus normalis* occurred. The peculiar mottled appearance of the two deposits is strikingly similar. We propose, however, to speak of this deposit in Browgill as the *Zone of Diplograptus acuminatus*.

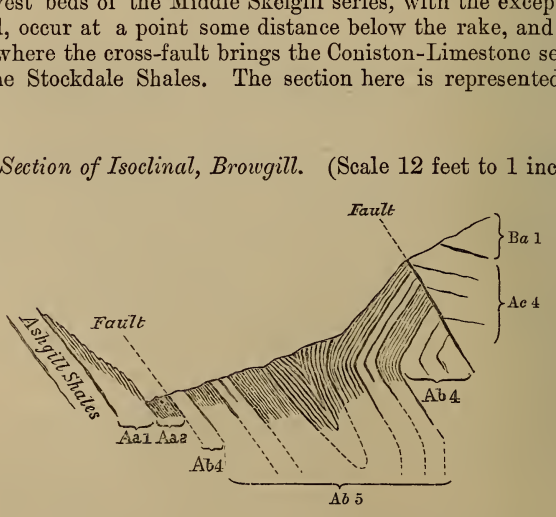
A*a* 2. Above this zone we find one or two feet of greatly disturbed, hard, black, mudstones, which we have little hesitation in referring to the *Dimorphograptus-confertus* zone; but the fossils are so badly preserved that we have not succeeded in extracting any which are capable of exact determination.

The disturbed character of the beds is due to their proximity to the strike-fault, the fissure of which comes immediately against them, and separates them from the overlying shales of the Middle Skelgill series. In this stream also we are therefore unable to estimate the thickness of the *Dimorphograptus-confertus* zone, or of the lowest subdivision of the Middle Skelgill beds.

At the rake itself a considerable thickness of the Middle Skelgill beds is missing, and the shales of the *convolutus*-zone are the lowest beds of this group which are seen. Some yards above the rake, the beds A*a* 3 of the *M.-fimbriatus* zone are seen, much broken, but with specimens of *Monograptus fimbriatus*, Nich., beautifully preserved in relief. The character of the beds is that of the representatives in the typical section; but as they are faulted above and below (the main strike-fault passing below them), they present little of interest.

The lowest beds of the Middle Skelgill series, with the exception just noted, occur at a point some distance below the rake, and not far above where the cross-fault brings the Coniston-Limestone series against the Stockdale Shales. The section here is represented in fig. 3.

Fig. 3.—*Section of Isoclinal, Browgill.* (Scale 12 feet to 1 inch.)



The Lower Skelgill beds are seen occupying the same position as at the rake, but only one foot of the shales which we refer to the *Dimorphograptus*-zone is found below the strike-fault. Another

fault, which dies out before we reach the rake, brings the Browgill Beds against the Middle Skelgill Beds, and between the two faults these latter occur in an overfolded synclinal, as shown in the figure. The lowest beds seen belong to A*b* 4, the *glaber*-zone, of which a few inches are seen in contact with the Lower Skelgill Beds, whilst two feet are visible resting against the second fault. These beds are blue mudstones, of the same character as those we have had frequent occasion to describe, but we have found no fossils therein at this spot. Their identification is rendered certain by their position, for they pass into the newer beds of the synclinal.

It is evident that the strike-fault between the Lower and Middle Skelgill Beds is more important here than at Skelgill, and the result is that the zones of *Encrinurus punctatus* and *Monograptus argenteus* are unrepresented in this section.

A*b* 5. Continuing the description of the beds in the isocline, we observe the *glaber*-mudstones passing up into 1 foot 6 inches of black shales, in which the Graptolites are well preserved in relief.

Succeeding these are some pale-greenish mudstones apparently devoid of fossils, and above them we meet with about four feet of blackish shales, with olive-brown staining along the joint-surfaces, and containing *Monograptus convolutus* with its usual associates. The list of fossils found in these shales in Browgill will be enumerated after describing the shales of this zone seen at the rake; but in the meantime we would mention that we found one specimen of *Petalograptus cometa* a few inches below the pale-green mudstones in the inverted limb of the syncline, and therefore in newer beds.

The band of black shales between the pale-green mudstones and the *glaber*-zone is, as at Skelgill, marked by the occurrence of great quantities of *Diplograptus tamariscus*, Nich.

We have called particular attention to this isoclinal fold, because such are most exceptional in the Stockdale Shales between Browgill and Coniston Waterhead, and it is the rule along that country to find members of the series faulted out, and not reduplicated.

To return to the section at the rake:—

A thickness of one foot four inches of the *convolutus*-shales is seen immediately above the strike-fault, these forming the extreme summit of the zone, and passing up into the mudstones of the succeeding zone. These shales are quite like those of the *convolutus*-zone in Skelgill, viz. greyish-blue shales, with olive-brown stains along the joint-surfaces.

We have obtained from the *M.-convolutus* zone of Browgill:—

Monograptus convolutus, *His.*
—— gregarius, *Lapw.*
—— Nicoli, *Harkn.*
—— proteus, *Barr.*
—— attenuatus, *Hopk.*
Rastrites hybridus, *Lapw.*
Retiolites perlatus, *Nich.*
Diplograptus Hughesii, *Nich.*
—— tamariscus, *Nich.*
Petalograptus cometa, *Gein.*

A*b* 5. The beds into which the shales of the preceding zone pass up consist here of pale-green mudstones, having a very ferruginous, calcareous, nodular band near the summit; the whole has a thickness

of only two feet, and we have obtained no fossils from it, but it is shown by its position to be the representative of the "Barren Band" of Skelgill.

Ac 1. The preceding beds pass into three feet of Graptolitic shales of a leaden colour, except near the centre, where they are blacker. This is the *Clingani*-band, and, like the corresponding band at Skelgill, it contains a great abundance of *Climacograptus normalis* along certain lines, along with:—

Monograptus Clingani, *Carr.*
—— Nicoli, *Harkn.*
Monograptus crenularis, *Lapw.*

M. Clingani is the prevailing form.

Ac 2. The overlying mudstones, which present the usual passage into the shales above and below, are only one foot five inches in thickness. They consist of pale-green, calcareous shale, with numerous dendritic markings, and containing few fossils except along one bedding-plane, where they are very numerous, indeed far more so than in any one of the non-Graptolitic bands of the Stockdale Shales of any other locality whatsoever. Two nodular, calcareous bands are seen near the centre of the zone, with the usual chocolate-coloured earthy residue left where the nodules are weathered out, and between these bands occurs the bedding-plane alluded to above. Besides this, a few fossils are found in the lower calcareous band. Fossils:—

Ampyx aloniensis, n. sp.
Harpes judex, n. sp.
Calymene Blumenbachii, *Brongn.*
Proëtus brachypygus?
Encrinurus punctatus, *Wahl.*
Phacops mucronatus, *Brongn.*
Phacops elegans, var. glaber.
—— elegans, *Bœck & Sars.*
Acidaspis.
Leptæna quinquecostata, *M'Coy.*
—— *cf.* sericea, *Sow.*

Also occasional plates of a Cystidean.

Very many heads of the *Ampyx* are seen, and all the fossils of the *A.-aloniensis* zone of Skelgill appear to occur here, with a few others, so that there would be no difficulty in fixing the horizon of the zone, even if it were not seen in the same position as at Skelgill, viz. between the *Clingani*-band and the *spinigerus*-zone.

Ac 3. The *spinigerus*-zone of Browgill is about two feet thick; but the passage into the mudstones above is so gradual that it is difficult to fix upon the exact line of demarcation. The lower part of the zone consists of black shales, weathering olive-brown, and with many Graptolites along certain bands, whilst the upper part is composed of shales of many colours, some showing the lozenge-pattern also found in the beds of this zone at Skelgill and, indeed, in all places where it is well developed throughout the district, so that we need not call attention to this feature in our future descriptions of the sections.

Monograptus spinigerus occurs as usual in countless multitudes, with its customary associates, which we did not trouble to collect; but one specimen of *Rastrites hybridus* was obtained, and we call attention to it, as it has not turned up in the *spinigerus*-zone elsewhere.

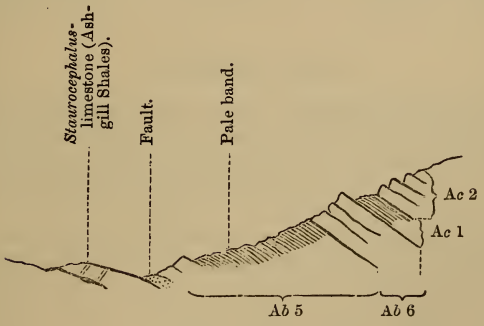
Ac 4. The highest beds consist of the blue mudstones, which occur between the *spinigerus*-zone and the Browgill Beds; these are here ten feet in thickness, and contain a calcareous nodular band of the usual description, ten inches thick, and at a distance of three feet from the base. No fossils have been found here in these mudstones of the *erinaceus*-zone, and their passage up into the Browgill Beds has been already described.

The section in Stockdale Beck below the cascade over the Coniston Limestone is, so far as the Skelgill Beds are concerned, quite like that occurring at the rake in Browgill; for we get the *convolutus*-beds as the lowest zone developed, and above it the remaining zones of the Middle Skelgill, and all the zones of the Upper Skelgill Beds occur just as there, so that further description is unnecessary. The strike-fault below the shales of the *convolutus*-zone is marked by a depression down which a rivulet trickles from a swamp in the field above, and this fault appears to bring the *convolutus*-beds actually against the Coniston Limestone, though there is a short interspace, marked by the above hollow, in which no rock is seen.

Stile End.

The Stockdale Shales are apparently shifted to a slight extent by a dip-fault, or probably a complex of such faults, running down the Long Sleddale valley; but as the lower parts of the valley are here occupied by alluvium and drift, no section of the beds is seen until after mounting the hill on the west side of the valley for a considerable distance. About halfway up the Stile End Pass, shales

Fig. 4.—*Section near Stile End.* (Scale 12 feet to 1 inch.)



belonging to the *Dimorphograptus*-zone are seen cropping up on the moorland; but the exposure is a small one and of little interest. Still higher up, and a very short distance below the summit of the pass, on the Long Sleddale side, a section of the Skelgill Beds is found on the right bank of a small stream to the south of the path (see fig. 4).

The base of the Ashgill-Shales series occupies the left bank of the

stream, down which the usual strike-fault runs, and the lowest beds seen on the right bank are mudstones, of which a thickness of 1 foot 6 inches occurs. Above this are 5 feet 8 inches of Graptolitic shales, having the ordinary lithological characters of the *convolutus*-zone, and containing its fossils. A pale-green band, two inches thick, occurs a foot above the base of these shales, and at first sight it appeared as though the shales, with many specimens of *D. tamariscus*, would occur beneath this; but this was found not to be the case, and we believe that the mudstones at the bottom of the section belong to the *convolutus*-zone, and that the shales with many specimens of *D. tamariscus* should occur beneath this, and are not here exposed. Fossils :—

Monograptus convolutus, *His.*
—— leptotheca, *Lapw.*
—— gregarius, *Lapw.*
—— Nicoli, *Harkn.*
Rastrites urceolus, *Richter.*
Rastrites hybridus, *Lapw.*
Diplograptus tamariscus, *Nich.*
Climacograptus normalis, *Lapw.*
Aptychopsis.

A*b* 6. The Barren Band here consists of two feet ten inches of blue mudstones, passing down into the beds below. (It will be convenient if we remark that a passage is understood unless otherwise intimated.) It yielded *Leptæna quinquecostata*, M'Coy, and *Whitfieldia tumida*, Dalm. ?

A*c* 1. The *Clingani*-band is represented by one foot of grey-blue Graptolitic shale, with the usual fossils accompanying the characteristic small *M. Clingani*, and above it is A*c* 2, the *Ampyx-aloniensis* zone, of which only two feet are seen, and which yielded no fossils.

The Browgill Beds occur in isolated outcrops on the moorland, at several places between Long Sleddale and Kentmere, but they present little of interest.

Kentmere Sections.

No section of any importance occurs on the east side of the Kentmere valley, the hill-sides being largely occupied with turbary. A number of dip-faults run down the valley, shifting the beds to some extent, and the first good section of the Stockdale Shales is seen in the bed of the Kent, just east of the church. Only the upper portion of the Browgill Beds occurs here, with the usual fine, hard, greenish-grey grit interstratified with shales; but the passage into the Coniston Flags is admirably displayed, the Browgill Beds having interstratified bands of blue mudstones towards the summit, until at last these preponderate, and the pale bands become rarer, and finally disappear altogether, the complete passage taking place in the course of twenty or thirty feet.

On the west side of the valley the dip-faults become very numerous, and the beds are greatly shifted laterally, as shown by the outcrop of the Coniston Limestone; but we meet with no exposures of the Stockdale Shales until arriving at a point some distance above the bottom of the Kentmere valley. Here two small

streamlets unite at the 900-feet contour-line to form a tributary of Hallgill, and the southernmost of these displays the Stockdale Shales dipping to the S.S.E., and striking transversely across the beck.

The lowest bed seen belongs to the zone of *Ampyx aloniensis*, and one of the calcareous nodular bands is seen in it, and above it is the base of the *spinigerus*-zone, composed of black earthy shales crowded with *Monograptus discretus*, Nich., and containing also *M. jaculum*, Lapw., and other fossils. Above this is a short interval, and then the upper part of the *spinigerus*-zone comes on, exhibiting the usual variegated shales, with :—

Monograptus spinigerus, *Nich.*	Diplograptus modestus, *Lapw.*?
—— jaculum, *Lapw.*	Petalograptus palmeus, *Barr.*
—— distans, *Portl.*	Climacograptus normalis, *Lapw.*
—— crassus, *Lapw.*	Retiolites perlatus, *Nich.*
Rastrites urceolus, *Richter.*	Peltocaris.
Diplograptus tamariscus, *Nich.*	

These shales are succeeded by 10 feet of blue mudstone, belonging to the *A.-erinaceus* zone, in which no fossils have been found here.

These pass into the Browgill Beds, some feet of which are seen in the stream, after which is a gap in the place where the *turriculatus*-bearing black band should occur. No signs of it are visible. Above this are more pale-green shales, with a few black bands containing badly preserved Graptolites. Some of the bands are probably covered up, for in the stream immediately below this are loose fragments containing the Graptolites characteristic of the *M.-crispus* zone, including :—

Monograptus crispus, *Lapw.*	Monograptus jaculum, *Lapw.*
—— exiguus, *Nich.*	Petalograptus palmeus, *Barr.*
—— discus, *Törnq.*	Retiolites Geinitzianus, *Barr.*
—— pandus, *Lapw.*	

Troutbeck Valley.

A marked depression indicates the position of the Skelgill Beds above the section just described, and an isolated exposure on the moorland just south of the summit of the Garbourn Pass furnishes the following fossils of the *fimbriatus*-zone :—

Monograptus fimbriatus, *Nich.*	Climacograptus normalis, *Lapw.*
Diplograptus tamariscus, *Nich.*	Orthoceras araneosum, *Barr.*
—— sinuatus, *Nich.*	

Proceeding to the Troutbeck side of the pass, the depression marked by the mudstones or, rather, more probably by a fault which cuts them out entirely, is seen running diagonally down the hillside towards Troutbeck church, shifted laterally by some small dip-faults, and crossing the Garbourn road just below the large flag-quarries. On the hillside above this depression are several exposures of and quarries in the Browgill Beds, but no continuous section. On reaching the bottom of the valley the beds are shifted

half a mile to the north by the great dip-fault, and the next section in the Stockdale Shales is met with in Scot Beck. A dip-fault runs down this stream, bringing the Stockdale Shales of the left bank against the Ashgill Shales on the right. The hard mottled pyritous limestone of the *Atrypa-flexuosa* zone is seen on the left of the stream, containing no fossils here. Above it are two or three inches of hard, bluish-black, unfossiliferous shales, apparently belonging to the *Dimorphograptus*-zone, and above these is a smashed mass of shales with a few badly preserved Graptolites, including *Monograptus fimbriatus*, Nich., *M. concinnus*, Lapw., and *Petalograptus ovato-elongatus*, Kurck, belonging to the *fimbriatus*-zone. The usual strike-fault evidently occurs at the base of these, and accounts for their crushed condition. Lower down the stream the Browgill Beds are seen, with many black bands, which are greatly hardened, and no fossils were seen in them. Immediately to the west of this a drain was cut in 1886 in the field, and exposed the *spinigerus*-beds with beautifully preserved specimens of *Monograptus spinigerus*; and at the summit of these were a few inches of the mudstones of the *erinaceus*-zone. After crossing a mass of Coniston Limestone brought against the Stockdale Shales by trough-faults, the depression marking the position of the (probably) faulted-out Skelgill Beds may be traced westward across Nanny Lane, after which it bends to the south-west, and so is continued into Skelgill at the Upper Bridge, as previously described. On the moorland to the south of this depression are many small quarries in the Browgill Beds, which contain numerous minute and indeterminable Brachiopods. These beds are traceable on the high ground to the south-east of the beck to near High Skelgill Farm.

Skelgill.

It will be remembered that the Skelgill Beds were last seen where the stream left the wood and ran for a few yards over a swampy tract. It here turns due south, and is presently crossed by the bridge leading to High Skelgill Farm. The Browgill Beds first appear in the stream just above this bridge, and consist of pale green shales, interstratified with which are a number of indurated grey bands, the lamination-planes of which are marked with minute wrinklings, which render the contained Graptolites undeterminable. They are almost certainly the *crispus*-beds, the *turriculatus*-beds being concealed under the alluvial material higher up the stream. About 30 yards below the bridge the calcareous nodular bands forming the base of the Upper Browgill Beds are found, and are succeeded by the usual pale shales with interstratified grit bands, with which no Graptolite-shales were seen; and these pass up, in the way described when dealing with the Kentmere section, into the Lower Coniston Flags, which contain well-preserved fragments of vomerine Graptolites. Beyond this the beds strike through Dove-nest Wood to the eastern shore of Windermere.

Pull Beck.

The extensive bay of Pull Wyke, on the west side of Windermere and close to the head of the lake, is due to the soft rock of the Stockdale Shales, which are masked to the westward by the existence of an alluvial flat, through which the stream called Pull Beck runs. Crossing over this stream by the bridge over which the Coniston road runs, we may follow the latter road past the great Brathay Flag-quarries to a cart-track which turns to the right through a gate immediately beyond the quarries. If we follow this cart-track we are presently brought down to the stream near some cottages. The Skelgill Beds are exposed in numerous more or less isolated outcrops in the bed and banks of the stream and in the lane north of the cottages; but they are so cut up by numerous minor dip-faults as to assume the character of a fault-breccia on a large scale, and any attempt to make out a succession is futile. The *Atrypa-flexuosa* limestone is seen in the lane north of the cottages, and has the same character as at Skelgill; but no fossils were found here. The *Dimorphograptus-confertus* Beds occur in the stream by the bridge at the cottages, and contain numerous well-preserved specimens of *Monograptus revolutus*, Murch. The Middle Skelgill Beds are seen in many places, and the fossils of most of the zones can be collected in an admirable state of preservation, as the beds in this faulted tract have escaped to a great extent the effects of cleavage. In the wood west of the cottages a small exposure of the *aloniensis*-zone occurred and yielded an excellent specimen of *Proëtus brachypygus*, n. sp. Beyond the wood the stream runs through a few fields to a small spinney called Redding Coppice, and there receives a tributary from the west, whilst the main stream flows from the south-west. In the main stream, just above the point of junction with the tributary, the black bands of the *crispus*-zone occur, and the fossils at this point are in a better state of preservation than in any other exposure of this zone which we have met with. They include:—

Monograptus crispus, *Lapw.*
—— exiguus, *Lapw.*
—— pandus, *Lapw.*
—— discus, *Törnq.*
—— Hisingeri, *Carr.*
Cyrtograptus? spiralis, *Gein.*
Retiolites Geinitzianus, *Barr.*
—— perlatus, *Nich.*, var.
Petalograptus palmeus, *Barr.*
—— ——, var. tenuis.
Peltocaris.

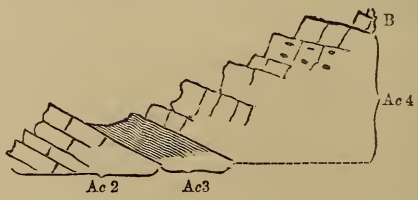
Higher Browgill Beds occur further up the stream. Just west of this point a great dip-fault shifts the beds five sixths of a mile to the south, and the pale shales of the Browgill Beds are seen in a beck coming down the hill from the west, just south of Sunny Brow. Here they are of no great interest, and although several exposures of Browgill Beds and occasional patches of the Skelgill Beds are seen between here and the Coniston Valley, no section of particular interest is found till Coniston Waterhead is reached. There are some exposures of Skelgill Beds in a stream near the Waterhead Hotel; but the best sections occur further west.

Yewdale Beck.

Just east of the Waterhead Hotel another great north-and-south fault, ranging down Coniston Lake, shifts the beds to the north a distance of nearly a mile, and accordingly we again meet with the Stockdale Shales in Yewdale Beck, which flows through the Yewdale Valley west of Tarn Hows Wood, in a south-westerly direction, and consequently parallel with the strike of the beds, which between Sunny Brow and Broughton Mills is north-east and south-west instead of east-north-east to west-south-west. At this point are some saw-mills, which are about half a mile north of Coniston church; and above the weir belonging to these mills the *Dimorphograptus-confertus* beds are seen striking slightly obliquely across the stream, and are again met with some yards higher up after crossing a meadow. There is an apparent thickness here of at least 50 feet; but an examination of the beds suggests much repetition. They occur in a series of lenticular masses, so as to produce a simulation of false-bedding, and the beds are extremely indurated, the lamination-planes being marked with minute wrinklings, which render the fossils, abundant enough, generally undeterminable. We recognized *Monograptus revolutus*, Kurck, and *M. tenuis*, Portl. A strike-fault ranges along the south-east bank of the stream and brings the Middle Skelgill Beds against the *Dimorphograptus*-beds, cutting out the lower portion of the middle group, so that the zones of *Monograptus fimbriatus*, *Encrinurus punctatus*, *Monograptus argenteus*, and part of the zone of *Phacops glaber* are absent. The upper part of the *Phacops-glaber* zone is seen passing into the *convolutus*-beds, of the usual appearance, and containing the usual fossils; but the summit of this bed is not seen at any accessible point, and, indeed, the next beds we were able to examine were those belonging to the zone of *Acidaspis erinaceus*, which were seen passing up into the Browgill Beds.

Following the beck to the cluster of houses known as the Far End another exposure is reached where the beck turns sharply to the south-south-east, and the Stockdale Shales leave the beck and

Fig. 5.—*Section at Far End, Yewdale Beck.*
(Scale 12 feet to 1 inch.)



strike across the drift-covered country in the direction of the railway-station. At this turn of the stream the above section is met with (fig. 5). The *Ampyx*-zone (4 feet seen) is succeeded by the

spinigerus-zone (2 feet thick, but somewhat crushed), which yielded, to a brief search,

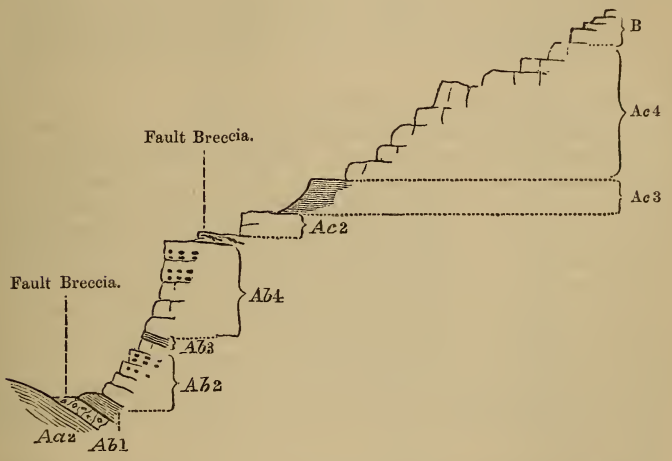
Monograptus spinigerus, *Nich.*	Diplograptus Hughesii, *Nich.*
—— distans, *Portl.*	

Two calcareous nodular bands of the ordinary kind occurred near the top of the *erinaceus*-zone, which shows the usual passage into the Browgill Beds, and is here 10 feet thick.

Mealy Gill.

Half a mile after leaving Yewdale Beck the Stockdale Shales are again met with in Church Beck, where this stream is joined by a tributary coming from the south-west known as Mealy Gill, and a good section of the shales is exhibited in a wooded gully through which the latter runs, and is found just above the bridge over which a siding from the railway-station is carried.

Fig. 6.—*Section in Mealy Gill.* (Scale 12 feet to 1 inch.)



The lowest beds seen are on the north-west bank of the stream, as seen in fig. 6, which shows a restored section taken from different parts of the gill, so as to exhibit all the zones which we have detected here in the Skelgill Beds. The Lower Skelgill Beds occupy a great part of this bank, but in one place a fragment of the *fimbriatus*-zone occurs in which the fossils are beautifully preserved. They include:—

Monograptus fimbriatus, *Nich.*	Petalograptus ovato-elongatus, *Kurck.*
—— leptotheca, *Lapw.*	Climacograptus normalis, *Lapw.*
Rastrites peregrinus, *Barr.*	
Diplograptus sinuatus, *Nich.*	

In most cases, however, the usual strike-fault runs up the bed of the stream, and the Middle Skelgill Beds are developed only on the right bank. About halfway between the railway-bridge and a waterfall which flows over the smashed Lower Skelgill Beds is a precipitous cliff-section on the right bank, and at the base of this a few feet of much-broken shale of the *fimbriatus*-zone occur above the fault, having a gentler dip than the Lower Skelgill Beds of the opposite side of the stream.

A*b* 2. Above these *fimbriatus*-shales about 4 feet of mudstone of the *Encrinurus-punctatus* zone can be measured; but the junction with the *fimbriatus*-shales is not seen.

A*b* 3. The most interesting feature of this gill is the occurrence therein of the *argenteus*-zone, as this is the only section other than the typical one in which we have found it. It is a little thinner than at Skelgill, being only 6 inches thick, and is more strongly cleaved than at that place; but in the centre runs the remarkable pale green streak, one quarter of an inch thick, which is also found at Skelgill at a distance of 7 miles in a direct line.

Owing to the cleaved nature of the rock fossils are difficult to procure; but we found

Monograptus argenteus, *Nich.*	Diplograptus sinuatus, *Nich.*
—— leptotheca, *Lapw.*	Petalograptus ovatus, *Barr.*
—— cyphus, *Lapw.*	

The first-named occurs in considerable quantity.

A*b* 4. Six feet of the zone of *Phacops glaber* is seen above the *argenteus*-zone. It has the usual calcareous nodular bands, as has the *punctatus*-zone in this section. A fault is seen above this with what are apparently some of the *convolutus*-shales crushed in the fissure in one place; but the next zone which is well developed is

A*c* 2, the zone of *Ampyx aloniensis*, so that the *convolutus*-zone, the Barren Band, and the *Clingani*-band are here cut out.

At the waterfall the section is similar, the very top of the *Encrinurus-punctatus* zone only is found above the fault, and this is succeeded by the *argenteus*-zone, which is close to the stream at the head of the fall, and is succeeded by some *Phacops-glaber* mudstones, after which the second fault brings the zone of *Ampyx aloniensis* against these.

A*c* 3. The *spinigerus*-shales of normal character, but somewhat crushed, 2 feet thick, but possibly some crushed out altogether. They contain abundance of *Monograptus spinigerus*, Nich., along with *M. lobiferus*, M'Coy, *M. distans*, Portl., *Diplograptus tamariscus*, Nich., &c.

A*c* 4. The zone of *Acidaspis erinaceus* is from 8 to 10 feet thick so far as can be seen, and the mudstones pass up into the Browgill Shales.

The beds of the last two zones are seen on the moorland on the right bank and a turn in the stream causes the beds of the *erinaceus*-zone to strike into the stream, where the Browgill Beds overlie them. Twenty-one feet of pale green shales are succeeded by a black band

1 inch thick, which is greatly hardened, and is probably the band containing *Monograptus turriculatus*, Barr.; but we could obtain no fossils therefrom. About 8 feet of pale green shales overlie this, and then several black bands like those of the *crispus*-zone are interstratified with the pale shales; but they too have had their fossils obliterated.

A little to the south-west of the section just described the beds are shifted somewhat to the north by a dip-fault, and the line of outcrop of the Skelgill Beds may be followed by a line of depression, along which runs Braidy Beck, a tributary of Mealy Gill, to a pool of water known as Boo Tarn, and then onward alongside the Walney Scar road, and over a peat-moss to Torver Beck, which is a mile and a quarter to the south-west of the section last described. Along the whole of this distance frequent exposures of the Browgill Beds are seen on the moorland; but there is no feature of any interest to record.

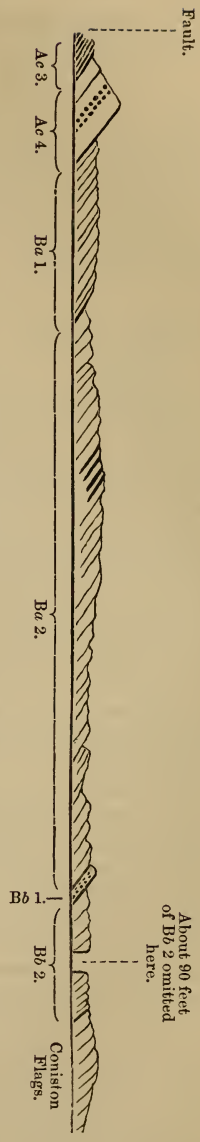


Fig. 7.—*Section in Torver Beck.* (Scale 48 feet to 1 inch.)

Torver Beck.

This stream runs from Goat's Water at right angles to the strike of the beds. West of the large flag-quarry of Tranearth the depression above mentioned crosses the beck, and there is certainly a strike-fault across the stream here, as there is little space in which no rock is exposed, and a considerable amount of the Coniston-Limestone series and nearly all the beds of the Skelgill group are unseen.

To the east of the fault the section shown in fig. 7 is seen.

Ac 3. The *spinigerus*-zone is the lowest band visible. The beds are much broken against a minor fault which crosses the stream transversely, and a dip-fault also runs on the north-east side of the beck, displacing the beds of the *erinaceus*-zone. Above the small transverse fault are two or three feet of the *spinigerus*-shales, which are here blacker than is usually the case, and contain fossils preserved in relief,

a mode of occurrence somewhat unusual among the shales of this zone. The fossils are:—

Monograptus spinigerus, *Nich.*	Monograptus lobiferus, *M'Coy.*
—— crassus, *Lapw.*	Diplograptus tamariscus, *Nich.*
—— jaculum, *Lapw.*	Petalograptus palmeus, *Barr.*

Ac 4. These shales pass up into the mudstones of the *Acidaspis-erinaceus* zone. These are seen on the right bank of the beck, just above a wall, and bend round so as to occur with a slightly different strike on the left bank. They are 10 feet thick, and contain two bands of calcareous nodules near the centre, separated by about a foot of mudstone. Fossils are common between these nodular bands, and we have obtained here

Lindstrœmia, sp.	Phacops elegans, *Boeck & Sars.*
Acidaspis erinaceus, n. sp.	Leptæna quinquecostata, *M'Coy.*

All these forms are found abundantly, the *Acidaspis* usually in fragments, and perfect specimens are rare. These *erinaceus*-beds are shifted to the north-west for a distance of about ten paces by the dip-fault, and there come down to the stream, as the fault has now entered the bed of the stream.

The beds of the last zone pass up into the pale shales of the Browgill group, and there is a tolerably complete section of this group to the base of the Coniston Flags; but as the beds are much disturbed exact measurement is impossible. We find the following development of these beds:—

Ba 1. Fifteen or twenty feet of ordinary pale shale, surmounted by a thin seam of hard grey shale one inch thick, in which we obtained *Monograptus turriculatus*, Barr., in a bad state of preservation; but this is sufficient to show that these beds belong to the *turriculatus*-zone.

Ba 2. About 10 feet of pale shale, surmounted by 20 feet of black shales interstratified with pale bands, as is usual in the *crispus*-zone, and specimens of *Monograptus crispus* occurred here. About 20 feet of pale shale come on above this. These are the beds of the *crispus*-zone.

Bb 1. A pale band with calcareous nodules 2 or 3 feet thick, forming as usual the base of the Upper Browgill Beds.

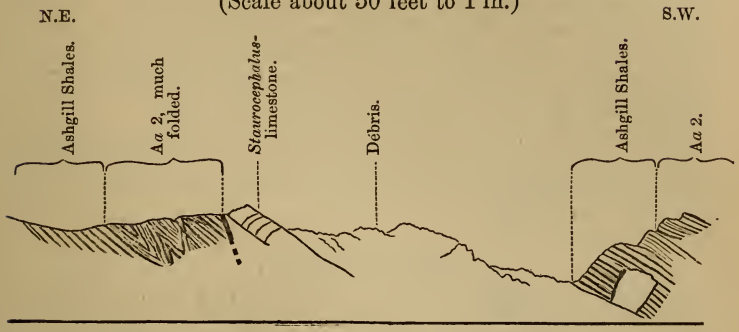
Bb 2. These uppermost beds of the Browgill group are less stained than usual, being mostly green, and contain the hard fine-grained grit-beds. Over 100 feet of these beds seem to be developed, so that the Browgill Beds in this section are about 200 feet in thickness. They pass up in the ordinary way into the Brathay Flags, below a waterfall. This and the section at Stockdale are the only two sections along the main line of outcrop which afford a fairly complete exhibition of the whole of the Browgill Beds.

Ashgill.

The usual depression is continued from Torver Beck to Ashgill Quarry, about two thirds of a mile to the south-west.

The section in the quarry is shown in fig. 8.

Fig. 8.—*Section across Ashgill Quarry.*
(Scale about 50 feet to 1 in.)



The *Dimorphograptus*-beds are seen in the face of the quarry resting on the Ashgill Beds, the *Atrypa-flexuosa* limestone being here crushed out. They are hard, ferruginous, well-laminated, grey-black shales, of glossy appearance, and with Graptolites, including *Monograptus revolutus*, Kurck, in a very indifferent state of preservation. *Dimorphograptus confertus* seems to occur here, but the shales are strongly cleaved, and sufficiently large pieces cannot be obtained to show the whole of any individual Graptolite. No higher beds of the Skelgill series occur.

In the south-west corner of the quarry a fault, which runs slightly obliquely to the strike, brings the *Dimorphograptus*-beds once more against the lowest part of the Ashgill Shales—the *Staurocephalus*-limestone. They are here seen to be affected by a series of folds, which causes reduplication of the shale. This is the clearest section we have seen exhibiting this feature; but we feel convinced that these shales are repeated often many times upon themselves all the way from Yewdale Beck to Appletreeworth Beck. Below the quarry no rock is seen for a considerable distance; but at the tail of what was once an island (though the south-western branch of the stream is now dry), about halfway between the quarry and Ashgill Bridge, the black shales of the *crispus*-zone crop out in the stream, associated with the usual pale shales. The fossils here are in a very tolerable state of preservation and include:—

Monograptus crispus, *Lapw.*
—— exiguus, *Nich.*
—— pandus, *Lapw.*
—— discus, *Törnq.*
Monograptus griestonensis, *Nicol.*
—— Hisingeri, *Carr.*
Retiolites Geinitzianus, *Barr.*
Petalograptus palmeus, *Barr.*

The *Retiolites* occurred only in the highest band visible. The whole thickness is about 20 feet. Just above Ashgill Bridge the

calcareous nodular band forming the base of the Upper Browgill Beds is seen, the intervening ground being covered with drift. A few feet above the calcareous band and on the other side of the bridge are some light shaly beds, stained pink, with a thin pebbly seam a quarter of an inch thick, about 7 inches from the summit. The pebbles are only about the size of a pea and are well rounded; and we mention this band as it is the only one which we have found in the whole Stockdale-Shale series which has any coarse material in it. Above this is a considerable thickness of pale shale with hard grits belonging to the Upper Browgill Beds; but the junction with the Lower Coniston Flags is not seen.

The depression caused by the Skelgill Beds or by the strike-fault runs in a south-westerly direction from this over a low col to the head of Appletreeworth Beck, which is reached in about one sixth of a mile from Ashgill.

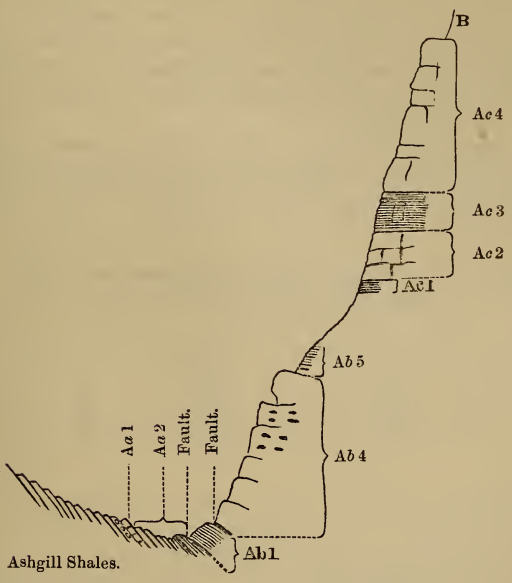
Appletreeworth Beck.

Sections in the Stockdale Shales are exhibited at intervals for over a mile between the head of the beck and Appletreeworth Farm. The stream runs in a south-westerly direction and along the strike of the beds, and we find the Lower Skelgill Beds as usual continuous with the Ashgill Shales and occurring generally on the north-west (right) bank of the stream, whilst the middle and upper beds and the Browgill group are developed on the left bank. No section of any importance need detain us until we reach a precipitous cliff a few hundred yards above the farm on the left bank of the stream. The section across the stream at this point is shown in fig. 9. The dip-slope is composed of the usual Ashgill Shales, at the summit of which is a band of large calcareous nodules, as at Skelgill. Immediately above this is a very thin, dark grey, calcareous band crowded with Ostracods and inseparable both from the Ashgill Shales below and the *Atrypa-flexuosa* beds above. We do not know whether to refer this Ostracod-bearing band to the lower or upper group; but it is a matter of no importance, as there is not the slightest doubt that a passage exists here. The *Atrypa-flexuosa* band is only 3 inches thick and consists of the usual light grey, mottled, pyritous limestone. The usual strike-fault runs down the stream; but at the upper end of the cliff it occurs some way off the stream on the left bank, and allows of the occurrence of about 15 feet of *Dimorphograptus*-shales with *Monograptus revolutus*, &c., in a small cliff. These beds are probably folded on themselves, as they exhibit a simulated false-bedded structure. At the point where our section is taken, lower down the stream, the fault has come to the bed of the stream, and below the line of section the thickness of beds rendered invisible by the fault increases, and higher and higher beds are brought against the Lower Skelgill Beds, until at last all the zones of the Middle and Upper Skelgill Beds are faulted out and the Browgill Beds rest against the Lower Skelgill Beds.

A little above the *Atrypa-flexuosa* band a thin bed occurs in the *Dimorphograptus*-shales, with small Brachiopods and *Turrilepas*, as at Skelgill.

A*b* 1. The shales of the *fimbriatus*-zone are seen on the line of our section at the base of the left bank of the stream; they contain

Fig. 9.—*Section across "Cliff" Appletreeworth Beck.*
(Scale 12 feet to 1 inch.)



Monograptus fimbriatus, Nich., *Petalograptus ovato-elongatus*, Kurck, *Rastrites peregrinus*, &c. A subsidiary disturbance is seen above them, removing the *Encrinurus-punctatus* zone, the *argenteus*-zone, and part of the zone of *Phacops glaber*; but about 10 feet of the latter remains with its nodular bands.

A*b* 5. The *convolutus*-beds are seen, but the exposure is not a very good one. We obtained *Monograptus convolutus*, His., *Rastrites hybridus*, Lapw., *Diplograptus tamariscus*, Nich., &c. A gap occurs here with no rock visible.

A*c* 1. The next rock above this gap belongs to the *Clingani*-band, a few inches of shale occurring with *Monograptus Clingani*, Carr., &c.

A*c* 2. The *aloniensis*-zone consists of blue mudstones about 2 feet 6 inches thick.

A*c* 3. The *spinigerus*-zone consists of many-coloured shales 2 feet 6 inches thick, with abundance of *Monograptus spinigerus*, Nich.,

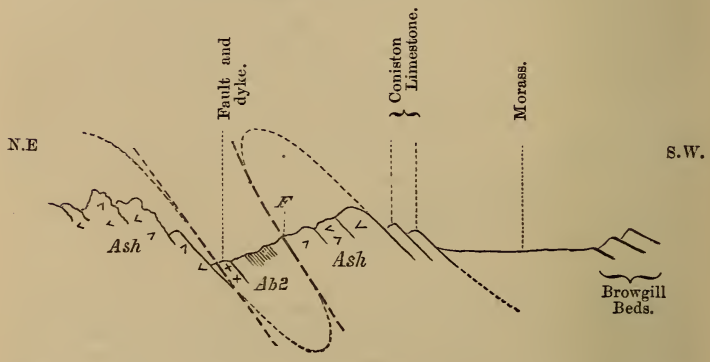
Monograptus distans, Portl., and the accompanying fossils, and is succeeded by

Ac4. The *Acidaspis-erinaceus* mudstones, 10 feet thick, and passing up into the Browgill Beds above. The latter are difficult of access, and we were unable to work them in detail.

We have not collected carefully from the beds of this section, as they are much cleaved, and the fossils are very indifferent; we merely obtained sufficient to satisfy ourselves of the identity of the beds, and did not work the Trilobite-bearing mudstones at all for fossils; indeed, with the exception of one or two cases, we have left these latter untouched, knowing the time required, as a general rule, to extract any fossil remains from these comparatively barren bands, and knowing also that the identification of the Graptolitic zones above and below each mudstone band is sufficient to fix the position of the mudstone.

It has been stated that the strike-fault increases in intensity towards the south-west; and just below Appletreeworth Farm the disturbance has been so great as to produce the remarkable section seen in fig. 10.

Fig. 10.—*Section of Farm, Appletreeworth Beck.*
(Scale about 200 feet to 1 inch.)



We have here a faulted synclinal of Skelgill Beds brought beneath the Coniston Limestone by a fault which is shown, by the way in which it crosses the beck, to have a reversed hade. We would suggest that the fold which here brings up the Coniston Limestone has decreased to such an extent higher up the gill that there it only affects the Lower Skelgill Beds, repeating them upon themselves, a supposition for which we have given other evidence. If this is really the case, and the facts favour it strongly, the great apparent thickness of the Lower Skelgill Beds in Yewdale Beck and other sections is illusory.

The syncline of Skelgill Beds rapidly dies out to the south, as does the Coniston-Limestone anticline to the north, and the main outcrop of the Skelgill Beds proceeds to the south-west in a line

continuous with the morass represented at the right-hand side of our section. Though the depression can be followed to Broughton Mills, no exposure of the Skelgill Beds occurs, and only a few isolated patches of the Browgill Beds are seen.

Before leaving this section at the farm, we would add some further particulars.

The ashes seen in the extreme left of the section belong to a massive volcanic series, probably at this point below the whole of the Coniston-Limestone series, though, as is well known, similar beds are elsewhere intercalated between different members of the Coniston Limestone.

Along the fault between the volcanic rocks and the Skelgill Beds a felsite-dyke has burst, and this has baked the Graptolitic shales to a deep crimson colour. Specimens of this crimson shale can be obtained with the usual fossils of the *Dimorphograptus*-zone, viz. : — *Dimorphograptus confertus*, Nich., *Monograptus revolutus*, Kurck, and *M. tenuis*, Portl. The crimson shales appear to be included in the felsite ; and on the hillside south-east of the stream the normal black *Dimorphograptus*-shales are seen dipping to the south-east, and containing the same fossils as the altered portions. Above this is a gap with no rock seen, and further up the hill we meet with volcanic rocks like those at the extreme north-west of the section, succeeded on the brow of the hill by normal Coniston Limestone. This dips towards the morass seen in the right-hand portion of the section, and under this either the Skelgill Beds are concealed or the strike-fault which so frequently affects them runs, for on the other side of the morass the ordinary Browgill Beds are found passing into the normal Coniston Flags of the district without any further disturbance.

It has been observed that no section of any importance in the Stockdale Shales occurs between this point and Broughton Mills. Below the Mills an alluvial tract occupies the position of the Stockdale Shales ; and although the underlying Coniston-Limestone series is traceable at intervals along this line of strike as far as Millom, no further exposure in the Stockdale Shales is found on the west side of the Duddon estuary, though there is room in some places for the beds of this series between the Coniston Limestone and the Coniston Flags ; but in such cases the rock is concealed by alluvium.

Poaka Beck.

On the east side of the Duddon estuary an anticlinal fold brings up the Stockdale Shales in the neighbourhood of Dalton-in-Furness. In a paper in the ' Quarterly Journal ' for 1878 one of us refers to two specimens of *Stricklandinia lirata* as coming from the Browgill Beds of Rebecca Hill. The shale in which they occur is certainly like that of the Browgill Beds, but we have never met with any Brachiopods other than extremely minute ones in these beds, and we think it possible that the specimens preserved in the Wood-

wardian Museum have really been derived from one of the mudstone-bands of the Skelgill Beds.

The only section in the Skelgill Beds of the east side of Duddon which is known to us occurs in Poaka Beck, just above Bridge End, 3 miles to the north of Dalton-in-Furness. The section seen there is shown in fig. 11.

Fig. 11.—*Section at Poaka Beck.* (Scale 12 feet to 1 inch.)

A*a* 2?. The lowest beds seen are greatly disturbed, rusty-brown, weathered shales, with many ill-preserved Graptolites, of which the only one which we could determine was *Climacograptus normalis*, Lapw.; but from the general appearance of the shales we believe them to belong to the zone of *Dimorphograptus confertus*.

Above these shales is a considerable fault-breccia and then a space in which no rock is seen.

A*b* 6?. Two feet four inches of blue mudstone, the Barren Band or the summit of the *Ampyx-aloniensis* zone.

A*c* 1?. Very dark ferruginous mudstones, 8 inches thick, with few Graptolites. We obtained *Monograptus distans*, Portl., *M. Nicoli*, Harkn., and *Climacograptus normalis*, Lapw. We believe this to represent the *M.-Clingani* band, but did not see that fossil therein.

A*c* 2?. Pale green mudstone 1 foot thick. Either the *Ampyx-aloniensis* zone or a pale band interstratified with the *M.-spinigerus* shales.

A*c* 3. Banded black, grey, and pale mudstones, 2 feet 2 inches in thickness, with abundance of *Monograptus spinigerus*, Nich., and undoubtedly representing the *M.-spinigerus* zone.

A*c* 4. Blue mudstones of the *Acidaspis-erinaceus* zone, of which only the lowermost 6 feet are visible. At some distance above this on the hillside is a quarry in B, the pale shales of the Browgill Beds, which here contain unusually large cubic crystals of pyrites and many small undeterminable Brachiopods. There is little doubt that the bed we have marked A*c* 1 is really the *M.-Clingani* band, otherwise the *spinigerus*-zone would be of unusual thickness here, and we shall eventually point out that the beds tend to thin out in this direction.

The whole section is of little interest, and we call attention to it as it is the most southerly exposure of the Stockdale Shales in the Lake-district proper.

Having now traced the beds along their line of outcrop in the Lake-district, we may proceed to a description of the beds in those outlying districts to which we have previously referred.

Swindale Beck, Knock.

If we continue the line of strike of the Stockdale Shales in an east-north-easterly direction from Shap Wells it would pass near the village of Knock, under the Pennine Chain, and close to this village the Stockdale Shales actually do occur in Swindale Beck, and in a tributary which enters it from the north-east. In this tributary (Rundale Beck) some very black shales are seen, evidently separated from the surrounding rocks by a series of faults, and having a strike discordant with that of the adjacent rocks.

The beds are lithologically like those of the *fimbriatus*-zone, and though we have not found the characteristic fossil of that zone, there is no doubt from an examination of the appended list that the beds really do appertain to it.

Monograptus leptotheca, *Lapw.*
—— cyphus, *Lapw.*
—— tenuis, *Portl.*
—— triangulatus, *Harkn.*?
Rastrites peregrinus, *Barr.*
Petalograptus ovatus, *Barr.*
Diplograptus sinuatus, *Nich.*
—— Hughesii, *Nich.*
Climacograptus normalis, *Lapw.*

In Swindale Beck itself the highest Lower Palæozoic beds seen belong to the Lower Coniston Flags, and between these and the Coniston-Limestone series is a tolerable section of the Browgill Beds, though the section is by no means complete. The Upper Browgill Beds do not appear prominently, but the two Graptolitic zones of the Lower Browgill Beds are well represented. We could find no representatives of the Skelgill Beds in the main beck, and the lowest Graptolitic zone which is in the pale shales is only 1 inch thick; but it has yielded a great number of beautifully preserved specimens of *Monograptus turriculatus*, Barr., along with *Monograptus lobiferus*, M'Coy, and *Rastrites distans*, Lapw., showing that we have here the *turriculatus*-zone. This band occurred just above the level of the water, and is now almost entirely worked out, though the stream will doubtless cut a new exposure in time. A few feet above it are a series of black shales interstratified with pale shales and yielding the fossils of the *crispus*-zone. We have obtained from them:—

Monograptus broughtonensis, *Nich.*
—— pandus, *Lapw.*
Cyrtograptus Grayæ, *Lapw.*
Cyrtograptus? spiralis, *Gein.*
Retiolites Geinitzianus, *Barr.*
—— cf. macilentus, *Törnq.*

The Browgill Beds are here traversed by some mica-trap dykes, and the pink staining has affected the Lower Browgill Beds, a circumstance of unusual occurrence.

Spengill.

The existence of an anticlinal in the neighbourhood of Sedbergh was long ago described by Professor Sedgwick, and as a result of this fold we meet with beds of the Stockdale-Shale series in many of the streams in the valley of the Rawthey, on the north side of the anticlinal. By far the most complete of these sections is exhibited in a stream which runs down from Spengill Head in a southerly direction towards the farm of High Haygarth, about 5 miles east of Sedbergh, on the road to Kirkby Stephen. We shall speak of this stream as Spengill, a name which is more euphonious than that by which the stream is designated on the map of the Ordnance Survey. About 2 miles north of High Haygarth the main stream coming from the north is joined by a feeder from the north-west, and at the point of junction of the two streams a cart-track crosses a little ford. Above this an admirable exposure of the Stockdale Shales is afforded by a deep gully, and still further up in the bed of a shallower valley. A few yards below the ford a hard calcareous grit, one foot in thickness, was first pointed out to one of us by Professor Hughes; it occurs in a weathered exposure on the heathery right bank of the stream, by the side of the cart-track, and here fossils can readily be procured from it. In the Woodwardian Museum

Cornulites.
Orthis protensa, *Sow.*
—— biforata, *Schloth.*
Strophomena siluriana, *Dav.*
Meristella crassa, *Sow.*?

are preserved from this bed. The first four of these are found in the Ashgill Shales. This grit-band is succeeded by several feet of leaden-blue, cleaved, non-laminated mudstones, with abundance of *Phyllopora Hisingeri*, M'Coy, and *Myelodactylus*, sp. They are quite similar to the Ashgill Shales of other areas, and we believe that both these shales and the grit are referable to that horizon.

Some little distance above the ford a very hard limestone band, 6 inches thick, is exposed on the right bank of the stream just above water-level. It contains a few Crinoids, and we would take this as the base of the Stockdale Shales and as the equivalent of the *Atrypa-flexuosa* band. The section of the Stockdale Shales of Spengill is given in fig. 12, where this bed is marked A*a* 1.

A*a* 2. Immediately above this limestone are black, crushed shales with *Climacograptus normalis*, Lapw., and *Monograptus revolutus*, Kurck, and they pass into a series of greyish-black, very fissile shales, much stained with ferruginous matter, and crowded with Graptolites. These shales are seen on both sides of the stream. These beds dip at an angle of about 60° to the north, and the direction of dip is maintained by the overlying beds, though its amount becomes less in the upper portions of the Stockdale-Shale series. There is a thickness of at least 25 feet of the blackish shales, and as the dip is fairly constant it does not appear that the beds have been repeated. The fossils in these shales are :—

Monograptus revolutus, *Kurck.*
—— tenuis, *Portl.*
—— attenuatus, *Hopk.*
—— Sandersoni, *Lapw.*
Dimorphograptus confertus, *Nich.*
—— Swanstoni, *Lapw.*
Diplograptus vesiculosus, *Nich.*
—— modestus, *Lapw.*?

It will be seen that this list is identical with that of the Graptolites from an exposure of the *confertus*-shales a little below the Upper Bridge, Skelgill. As at that place, *Dimorphograptus confertus* is rare and *D. Swanstoni* abundant. We think it highly probable that the seams containing the abundance of *D. confertus* are crushed out from between these shales and the underlying calcareous band; but it is just possible that they may be on a higher horizon. Whatever be the relative position of the shales in which *D. confertus* is abundant and *D. Swanstoni* apparently absent, and those in which the latter is abundant and the former rare, there can be no question that the two belong to one Graptolitic zone, occurring always between the zone of *Atrypa flexuosa* or of its equivalent, that of *Diplograptus acuminatus*, and the zone of *Monograptus fimbriatus*.

A*b* 1. The actual passage between the *confertus*-shales and the succeeding Graptolitic shales is not seen; but we are disposed to believe that the junction is here an unfaulted one. If so, this is the only locality we have met with where such is the case.

There is no great gap between the *confertus*-shales and the overlying beds, and the two are dipping with perfect conformity. Moreover if a strike-fault did occur here, we believe we should find traces of it, as it is usual to get a considerable breccia developed at that point, and this breccia would almost certainly be exhibited. Be that as it may, the measured thickness of the

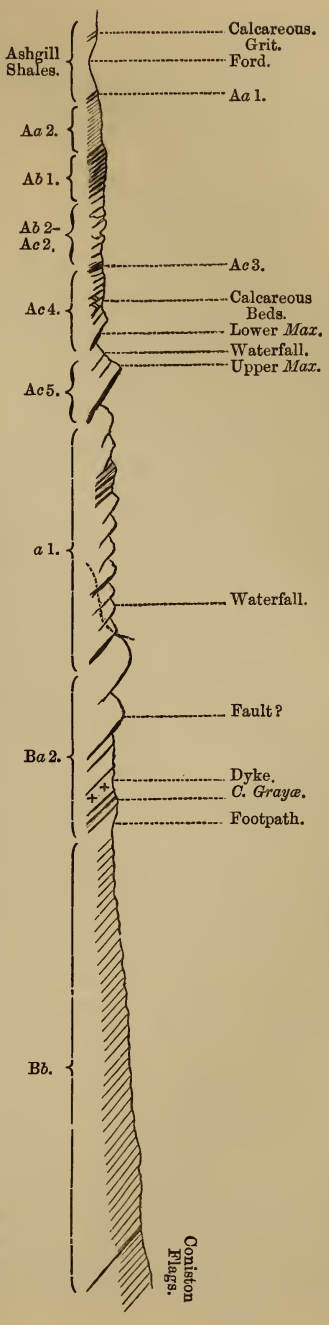


Fig. 12.—*Section in Spengill.* (Scale about 75 feet to 1 inch.)

confertus-beds is greater here than in any other section except where we have indications of repetition.

The shales above the *confertus*-beds are also Graptolitic and are very similar to the *confertus*-shales in lithological characters, being fissile and having a ferruginous staining due to weathering. The fossils are different :—

Monograptus fimbriatus, *Nich.*	Rastrites peregrinus, *Barr.*
—— gregarius, *Lapw.*	Diplograptus sinuatus, *Nich.*
—— attenuatus, *Hopk.*	Climacograptus normalis, *Lapw.*
—— triangulatus, *Harkn.*	

There is no doubt that these are the shales of the *fimbriatus*-zone, and another argument of the succession being here complete is furnished by the fact that *Monograptus triangulatus* is here very abundant, while elsewhere it is rare. It will be eventually seen that this form marks the lowest horizon of the representatives of the Middle Skelgill Beds in other areas.

The beds of the Middle Skelgill group above the *fimbriatus*-shales are extremely disturbed in this section. They are best exposed on the left bank of the stream. A crush occurs between the *fimbriatus*-shales and the succeeding beds, which are blue mudstones, probably forming the top of the zone of *Phacops glaber*, as the succeeding shales appear to belong to the *convolutus*-zone. In this case the zones of *Encrinurus punctatus* and *Monograptus argenteus* are entirely faulted out. As our time for examining this section was limited, and the Middle Skelgill Beds seemed to be of normal character, we did not work them out in detail, a task of some difficulty owing to their extremely folded condition. The beds which we refer to the *convolutus*-zone have the ordinary appearance of the shales of that horizon, and exhibit the very marked olive-brown staining which distinguishes its deposits. Above them are some blue mudstones; but a considerable fault occurs between the Middle Skelgill Beds and the lowest exposed beds of the Upper Skelgill group. The section of the representatives of this group is one of considerable importance, and we worked it carefully.

Ac 3. Returning to the right bank, an angle of the bank is seen jutting out into the stream at some little distance below a waterfall. In this angle some very black shales, interbedded with lighter bands, appear for about 2 feet below the overlying mudstones. The uppermost black shales have well-preserved Graptolites, including :—

Monograptus spinigerus, *Nich.*	Rastrites urceolus, *Richter.*
—— distans, *Portl.*	Diplograptus Hughesii, *Nich.*
—— leptotheca, *Lapw.*	Climacograptus normalis, *Lapw.*
—— lobiferus, *M'Coy.*	

Monograptus spinigerus occurs in the usual numbers, and indicates that this is undoubtedly the zone characterized by that species.

The succeeding beds of the Upper Skelgill group offer interesting differences from those of other sections.

Ac 4. No less than 30 feet of blue mudstones overlie the shales of

the *spinigerus*-zone, without the intervention of any Graptolitic shales. They contain many calcareous, nodular bands towards the summit, forming an impure limestone some 10 feet in thickness. Our attention was first called to this calcareous band by Prof. Hughes, and a number of fossils occur in it. We have found :—

Lindstrœmia, sp.	Cheirurus bimucronatus, *Murch.*
Favosites.	Illænus Bowmanni, *Salt.*
Phacops elegans, *Bœck & Sars.*	Leptæna quinquecostata, *M'Coy.*

The band strongly resembles that of the zone of *Acidaspis erinaceus* as seen at Torver Beck, and there is no doubt as to the identity of the two deposits, though the characteristic *Acidaspis* has not yet turned up in the Spengill section.

Ac 5. The zone about to be described has been found in no other section in the district, and indeed there is no doubt that it is absent all along the line of outcrop of the Stockdale Shales in the central district, as we have frequent opportunity of seeing a passage from the underlying beds into the Browgill group.

A waterfall in the Spengill section here separates the lower ravine which we have described from an upper one, and this waterfall is found to be determined by a mass of hard blue mudstones, which also form cliffs on each side. The cliff on the right bank is seen to form a projecting cornice, and immediately under this cornice 4 inches of very hard black Graptolitic shale occur. From this band we extracted a number of specimens of *Rastrites maximus*, Carr., and one example of *Monograptus jaculum*, Lapw. No doubt other fossils also occur; but the spot is a dangerous one, on account of the broken nature of the rock forming the cornice. These beds strike across the stream at the foot of the waterfall, and are again seen at the foot of the cliff on the left bank; but pieces of the shale are difficult to extract here. The characteristic *Rastrites maximus* was found here also. The blue mudstones above this band are 24 feet thick, and at the summit of them and forming the top of the cliff over which the water falls is another band, also 4 inches thick, very similar to the former, though lighter in colour, and likewise containing numerous examples of *Rastrites maximus*. We speak of these black shales with the intervening mudstones as constituting the *Zone of Rastrites maximus*.

The upper black band of the *R.-maximus* zone is at once succeeded conformably by the lowermost Browgill Beds.

Ba 1. The Browgill Beds occupy the upper ravine, which runs obliquely to the strike, so that we meet with a generally ascending succession, until we reach a second waterfall, which marks the upper end of this ravine. Above the *R.-maximus* beds are nineteen feet of ordinary pale green shale, after which we meet with four feet of pale green and bluish-grey bands with some thin dark seams. These are well seen on the right bank of the stream a little above water-level, and a few yards above the waterfall, where they are extremely conspicuous, owing to the stripes of the different-coloured bands. Above them are three feet of unstriped bluish-grey beds, on

the top of which rests a thickness of four inches of dark-grey, rather ferruginous shales, with *Monograptus turriculatus*, Barr., and *Rastrites distans*, Lapw., the former abundant and the latter rare. This bed is seen on both sides of the stream. Above it one foot two inches of pale shale separate it from another greyish-black band, four inches thick, with :—

Monograptus turriculatus, *Barr.*	Rastrites distans, *Lapw.*
—— Hisingeri, *Barr.*	

One foot six inches of pale shale intervenes between this and a third black band, also four inches thick, in which we saw no *M. turriculatus*, but *Rastrites distans* was procured therefrom.

These two upper zones are well seen at the top of a buttress of rock on the left bank of the stream, and also higher up, to the east of the waterfall. Fourteen feet of pale shale ensue, and then a concretionary grey bed about three inches thick, in which are no fossils, is met with, forming the extreme summit of the cliff over which the water falls at the head of the second ravine. This band may be traced along the lateral cliff on the right bank of the stream, and below the waterfall, and the ascending section followed from it. The beds below it are inaccessible on this side, until near the bottom of the dip where the banded rock already noticed occurs. Above the concretionary band we find in this cliff:—Green beds with fine shaly bands, many of them stained pink, and in some of which Graptolites are seen, but are poorly preserved, seventeen feet.

This shaly bed, five inches thick, and stained pink, crowded with *Monograptus turriculatus*, Barr., contains also :—

Monograptus rectus ?	Retiolites obesus, *Lapw.*

A total thickness of 61 feet 4 inches has been measured between the top of the zone of *Rastrites maximus* and this point, and we refer these beds to the zone of *Monograptus turriculatus*.

B*a* 2. Above the waterfall, the stream runs through a shallow valley, with exposures on each bank, but mainly on the left one. Above the uppermost *turriculatus*-band, we get thirteen feet of green beds with fine shaly bands, at the top of which there is reason to suppose the existence of a fault.

A thin blue-black band, sometimes stained pink, is next met with, and this yielded :—

Monograptus pandus, *Lapw.*	Cyrtograptus ? spiralis, *Gein.*
—— griestonensis, *Nicol.*	

This band is much baked by a dyke, and fossils are difficult to extract. It is two or three inches thick.

Two or three feet of pale shale lie between this Graptolitic shale and a felsite sheet breaking along the bedding and having a thickness of about twenty feet, and above it are twelve feet of ordinary pale shales somewhat baked ; the next band seen is very fine, grey, gritty shale three inches thick, one bedding-plane of which is covered with

the beautiful little *Cyrtograptus Grayæ*, Lapw., and the bed yielded also *Monograptus pandus*, Lapw., and a specimen of *Retiolites Geinitzianus*, Barr. The band is seen on the grass- and heath-covered left bank, and is succeeded by sixteen feet of ordinary pale shales, after which is a gap crossed by a footpath, in which there is room for about ten feet of rock.

We refer the beds between the uppermost *M.-turriculatus* band and this point to the zone of *Monograptus crispus*. There is little doubt that some of the beds are faulted out, either along the line of the dyke or below it, or both, and the shales which are seen are so baked that delicate forms like *Monograptus crispus*, if they originally occurred there, would be obliterated. The other species found all belong to the *crispus*-zone, and the zone is found in the immediate vicinity of this gill. About forty-four feet of rock has been measured belonging to this zone.

At the same time we would refer to the grey gritty shale as the *Cyrtograptus-Grayæ* band, believing it to form the very uppermost part of the *crispus*-zone. Above the footpath the section is less continuous.

B*b*. We believe that the footpath marks the line of separation between the Lower and Upper Browgill beds.

Above the footpath are fourteen feet of green shales, passing up into a great mass of red shales, with interstratified grits, which become greenish grey towards the summit, the whole having a thickness of about 160 feet. We have obtained no fossils from this portion, which is quite similar to the Upper Browgill group as developed elsewhere.

It will be seen that the Browgill Beds of this locality have a total thickness little short of 300 feet, and for diversity of character and richness of fossils they are unexcelled in any other part of the district.

River Rawthey.

The following Graptolites from black shales interstratified with pale green shales are preserved in the Woodwardian Museum; they were collected by Prof. Hughes at Rawthey Bridge and undoubtedly belong to the *crispus* zone:—

Monograptus exiguus, *Nich.*	Cyrtograptus spiralis, *Gein.*
—— pandus, *Lapw.*	Petalograptus palmeus, *Barr.*

The Browgill Beds are all well seen in Hebblethwaite Gill, on the south side of the Rawthey valley, and nearer Sedbergh than the last locality.

Professor Hughes has obtained *Monograptus turriculatus* from this stream, and we found bands with:—

Monograptus pandus, *Lapw.*	Petalograptus palmeus, *Barr.*
Cyrtograptus ? spiralis, *Gein.*	Retiolites Geinitzianus, *Barr.*

So that the two Graptolitic zones of the Browgill Beds appear to be here present.

Austwick Beck, near Settle.

The section here is described by Prof. Hughes in the 'Geological Magazine,' vol. iv., and one of us has given additional notes in the 'Geological Magazine,' dec. iii. vol. iv. The Bala Beds are succeeded here by a conglomerate of variable thickness, passing up into a limestone which contains Trilobites found in different zones in the Stockdale Shales; this limestone is immediately followed by the Lower Coniston Flags. Either the Skelgill Beds are absent, and the representatives of the Browgill Beds rest unconformably on the Bala Beds, or the conglomerate and succeeding limestone represent the whole Stockdale-Shale series. We shall revert to this question in the sequel.

Ribble Valley.

At Crag Hill, near Horton, Prof. Hughes describes a breccia-like limestone overlying the Coniston Limestone, in which he records the occurrence of *Favosites*. One of us has examined this.

There certainly is a strong resemblance between this limestone-conglomerate and the conglomerate of the valley, and the former like the latter occurs between the ordinary Coniston Limestone and the Lower Coniston Flags. We agree with Prof. Hughes therefore in referring the Crag-Hill calcareous conglomerate to the Stockdale-Shale series.

Teesdale.

We complete our description of the Stockdale Shales of the north of England by referring to the probable existence of Browgill Beds at Cronkley Mill, as described by Messrs. Gunn and Clough.

The accompanying figure (fig. 13) gives a general section through the Stockdale Shales, showing the full development of the zones. The thickness of the whole series varies from two hundred and fifty feet to over four hundred feet, the latter thickness being that of the beds in the Sedbergh district.

We append a table (pp. 726–729) showing the distribution of the fossils in the different zones of the Stockdale Shales.

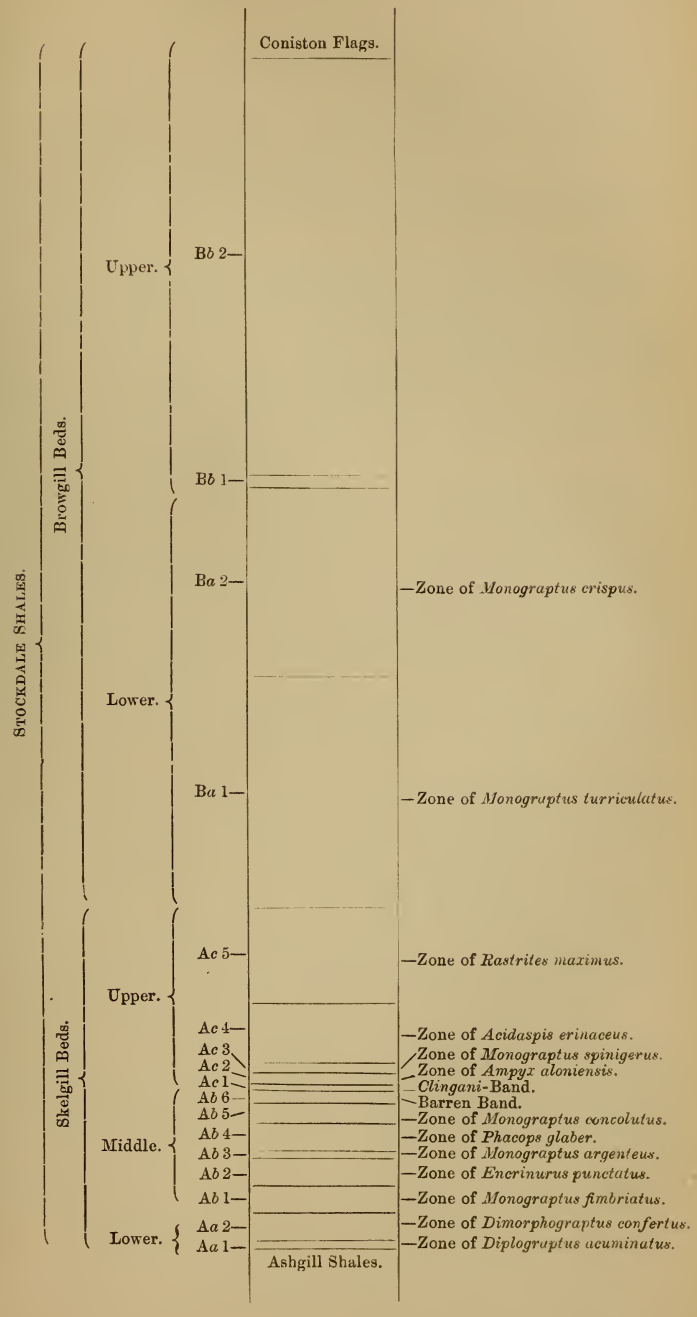
§ V. Comparison with corresponding Beds in other Areas.

One noticeable feature about the Stockdale Shales is the intercalation of non-Graptolitic beds containing more highly organized fossils with the Graptolite-bearing shales. We are thus enabled to compare the series with the corresponding Graptolitic beds of other areas as well as with non-Graptolitic ones.

We will commence with a comparison of our beds with the corresponding Graptolitic shales of the other areas, and we naturally start with those of the South of Scotland, which have been so admirably and clearly worked out by Professor Lapworth.

It is hardly necessary to insist on the similarity between the Skelgill Beds and the Birkhill Shales, and between the Browgill Beds

Fig. 13.—*Vertical Section of Stockdale Shales.*
(Scale about 1 inch to 50 feet.)



and those of the Gala group; indeed, Prof. Lapworth has himself shown the relationship of these in his papers on "The Moffat Series"* and "On the Geological Distribution of the Rhabdophora"†; but a most remarkable similarity between the Scotch and North of England beds becomes apparent when we come to compare the zones of each, for not only are the fossil contents of the zones of the two areas remarkably similar, but a decided resemblance can be traced when we compare the lithological characters.

The Lower Skelgill Beds are flaggy beds like those of the zones of *Diplograptus acuminatus* and *Diplograptus vesiculosus* at the base of the Birkhill Shales.

The Middle Skelgill Beds resemble the *Monograptus-gregarius* zone, not only in the blackness of the shales, but also in the development of interstratified mudstones containing calcareous nodules.

The Upper Skelgill Beds resemble the zones of *Monograptus spinigerus* and *Rastrites maximus* in that the beds are generally of a lighter colour than those of the underlying zones.

The Grits and pale Shales of the Browgill Beds are comparable with similar rocks in the Gala group.

Comparing the zones in detail:—

1. The zone of *Diplograptus acuminatus* at the base of the Birkhill Shales is like the same zone at the base of the Skelgill Beds. Both are slightly calcareous flaggy shales, and the two fossils found in the *acuminatus*-zone at Browgill, viz. *Diplograptus acuminatus*, Nich., and *Climacograptus normalis*, Lapw., both occur in the Birkhill zone. The two other species found in the Birkhill zone, *Dimorphograptus elongatus*, Lapw., and *Diplograptus vesiculosus*, Nich., have not yet turned up in the Lake-district; but possibly a further search will result in their discovery.

2. The zone of *Diplograptus vesiculosus*, Nich., is represented by the zone of *Dimorphograptus confertus*, Nich. In both areas the beds consist of black flagstones.

Of the fossils found in this zone in the Lake-district, *Monograptus tenuis*, Portl., *M. attenuatus*, Hopk., *Dimorphograptus elongatus*, Lapw., *Diplograptus vesiculosus*, Nich., and *Climacograptus normalis*, Lapw., are also found in the corresponding Birkhill zone.

Monograptus revolutus, Kurck, *M. Sandersoni*, Lapw., *M. leptotheca*, Lapw., *Dimorphograptus confertus*, Nich., *D. Swanstoni*, Lapw., and *Diplograptus longissimus*, Kurck, have not been recorded from the Birkhill Shales, but they are mainly found on one horizon in the Lake-district, and may eventually turn up in the Scotch area.

3. The zone of *Monograptus gregarius*, Lapw., is undoubtedly represented by the zones of *Monograptus fimbriatus*, *M. argenteus* and *M. convolutus*, with their interstratified mudstones. In all these zones *Monograptus gregarius* is abundant, and it is practically limited to them, only one specimen having been discovered in the *Clinganiband*.

Of the thirty-three species of Graptolites found in these zones in

* Q. J. G. S. xxxiv. p. 337.

† Ann. & Mag. Nat. Hist. ser. 5, vol. iii. p. 39.

the Lake-district, at least twenty-one also occur in the *gregarius*-zone of Scotland, whilst only four species found in the latter aefa are absent from the representative zones in the Lakes. The lithological resemblances have been already commented upon, and there can be no hesitation in correlating the Middle Skelgill Beds of the Lake-district with the zone of *Monograptus gregarius* of Scotland.

4. The succeeding subzone of *Petalograptus cometa* is not differentiated in our area. It appears to have thinned out; it is partly replaced by a mudstone band, or was formed contemporaneously with the uppermost portion of the *convolutus*-beds of the Lake-district; the latter contain *cometa* rarely, and all the forms found in the *cometa*-zone are also found in our *convolutus*-zone, with the exception of *Rastrites capillaris*, Carr., which is recorded in Prof. Lapworth's list at page 323 of his paper on the Moffat Series, but not in the general list at page 328.

5. The *Clingani*-band, which occurs at the base of the *spinigerus*-zone in Scotland, may be compared with our *Clingani*-band. Three of the four forms mentioned by Prof. Lapworth are found also in our band.

The Birkhill zone of *Monograptus spinigerus*, on the whole, bears a very striking resemblance to the zone containing this form in abundance in the Lake-district. The *Clingani*-band at Eldinhope Ruin is succeeded by 6 feet of soft greenish-grey shales without Graptolites. At Skelgill it has above it the 4 feet 6 inches of blue mudstones constituting the zone of *Ampyx aloniensis*. The many-coloured shales above are quite comparable to those of the upper part of the *spinigerus*-zone in Scotland, even to the occurrence of the lozenge-shaped patches on the rough surfaces of the harder beds. Of the Graptolites from the *spinigerus*-zone of the Lake-district, ten out of sixteen are found in the Birkhill Shales, or more than this if we count also those of the *Clingani*-band in our area, whilst three which occur in Scotland have not yet been found in our zone.

6. The abundance of *Rastrites maximus* in our uppermost zone of the Skelgill Beds shows its relationship to the highest zone of the Birkhill Shales. A fuller examination of the beds in the Spengill section would almost certainly result in the discovery of a more abundant fauna.

It is noticeable that the *maximus*-beds occur in pairs in Scotland; and Prof. Lapworth states that at Craigmichan only one pair is visible. We also have a pair of these beds separated by many feet of mudstone.

In this comparison we have not yet insisted upon what we consider of far more importance than the occurrence of a certain percentage of fossils common to the corresponding zones (for the percentages would certainly be considerably increased after further work), namely, the great abundance of the characteristic forms of the different zones in the corresponding order. We find:—

In the Lake-district:—	In the Moffat area:—
1. *Diplograptus acuminatus*, common.	*D. acuminatus*, common.
2. *D. vesiculosus*, common. *D. acuminatus* has disappeared.	*D. vesiculosus*, common. *D. acuminatus* has disappeared.
3. *Monograptus gregarius*, common. *Diplograptus vesiculosus*, very rare.	*M. gregarius*, common. *D. vesiculosus*, very rare.
4. Lack of abundance of *Petalograptus cometa*.	Abundance of *P. cometa*.
5. Abundance of *Monograptus spinigerus*. 1 specimen of *M. gregarius*.	Abundance of *M. spinigerus*. Absence of *M. gregarius*.
6. Abundance of *Rastrites maximus*.	Abundance of *R. maximus*.

Furthermore, our divisions of the Middle Skelgill Beds are, at any rate partially, suggested by an examination of the mode of occurrence of the Graptolites in the *gregarius*-zone of Scotland. Prof. Lapworth states that in his district "*Monograptus Sandersoni* (Lapw.) and *M. fimbriatus* (Nich.) are unknown above the central line" of the *gregarius*-zone. In our country they are found in the *fimbriatus*-zone, but not above it. Again, "*Monograptus triangularis* (Harkn.) occurs only in the neighbourhood of the nodule-band" which is near the centre; with us it is only found in the *fimbriatus*-zone. Lastly, "neither *Rastrites peregrinus* nor *Diplograptus vesiculosus* reach the summit of the group." We find the former confined to the *fimbriatus*-zone, and the latter rarely occurring in it, and not higher.

Passing now to the Browgill Beds, we find at first sight less striking resemblances in the more minute subdivisions; but this is partly due to the reference of the peculiar *Monograptus discus* to *M. turriculatus*, Barr., and the inclusion of *Monograptus pandus* with *M. priodon* in the published lists. Prof. Lapworth, in his paper on the "Geological Distribution of the Rhabdophora," p. 41, gives a list of fossils from the Gala group. Twenty-one species are there enumerated, of which twelve have been discovered by us in the Browgill Beds, and of these twelve only two pass down into the Skelgill Beds, and these only occur in the upper group. We cannot find any record of the separation of the *turriculatus*-beds as a distinct zone; they undoubtedly form such in the Lake-district, and the two forms *Monograptus turriculatus*, Barr., and *Rastrites distans*, Lapw., appear to be strictly limited to it in that area.

The fossils of the zone of *Monograptus crispus* are mostly found in the Gala group, and *M. exiguus* is a very common form in the two areas. In Prof. Lapworth's paper on "The Girvan succession" * the equivalents of the Gala group, the "*Crossopodia*-group," are divided into Lower Penhill Shales with *Monograptus exiguus* &c., Middle Penhill flags and greywackes, in which the Graptolites of the preceding beds recur, and Upper Penhill mudstones, or *Grayæ*-beds, with *Cyrtograptus Grayæ* and *Retiolites Geinitzianus*. It has already been pointed out that although we are unable to separate the *Grayæ*-beds and the beds with *Retiolites Geinitzianus* from the beds of our *crispus*-zone, we have found that they are limited to the upper

* Q. J. G. S. vol. xxxviii. p. 652.

part of it, and *Cyrtograptus Grayœ*, especially, occurs in such vast abundance in one seam at the very top of the *crispus*-beds, that we have thought fit to allude to this seam especially as the *Grayœ*-band.

Our comparison of the Stockdale Shales with the Birkhill and Gala groups renders unnecessary a minute comparison with the similar Graptolitic deposits in other areas. Such a comparison has already been successfuly instituted by Prof. Lapworth in his papers on the "Geological Distribution of the Rhabdophora" and on "The Moffat Series."

We merely proceed to add a few supplementary remarks, and in the first place call attention to some researches of the late Dr. Tullberg, published since the appearance of the above-mentioned papers of Prof. Lapworth. By Dr. Tullberg's early death science has been deprived of a most promising Graptolithologist and stratigraphical geologist, and his co-workers have lost a genial companion. In a paper "Om Lagerföljden i de Kambriska och Siluriska Aflagringarne vid Röstånga" * he suggests the following correlation of the beds of Scania and Scotland :—

Brachiopod-skiffer with *Phacops mucronatus*, Brongn.	= Lower Birkhill?
Lobiferus-skiffer.	= Upper Birkhill;

and divides the latter as follows :—

Shales with *Monograptus spinigerus*, Nich., *Diplograptus* (*Petalo.*) *cometa*, Gein., *M. gregarius*, Lapw., *M. cyphus*, Lapw., *M. Sandersoni*, Lapw., *Rastrites peregrinus*, Lapw., *Climacograptus normalis*, Lapw., &c.	= Zone of *M. gregarius*. „ „ *D. cometa*. „ „ *M. spinigerus*.
Shales with *Rastrites maximus*, not found in Scania.	= Zone of *Rastr. maximus*.
Retiolites-skiffer.	
Shales with *Monograptus crispus* &c.	= Gala and Grieston.
The latter succeeded by	
Shales with *Cyrtograptus Murchisoni* &c.	= Wenlock.

A fuller comparison is made by the same author † in a paper published in 1882. At the summit of the beds which he describes as appertaining to the Lower Silurian group or Ordovician, he places a dark-grey shale with *Diplograptus*, n. sp., and *Climacograptus scalaris*, Lapw., and an absence of *Monograptus*. This succeeds the zone of *Phacops mucronatus*, Ang., and most probably represents our zone of *Diplograptus acuminatus*. The *Rastrites*-beds are placed at the base of the (Upper) Silurian and are divided as follows :—

At the base is the zone of *Monograptus cyphus*, containing also a *Dimorphograptus*. We shall presently give reasons for concluding that this represents our zone of *Dimorphograptus confertus*.

* Geol. Föreningens i Stockholm Förhandl. 1880, No. 59, Bd. v. No. 2.

† "Skånes Graptoliter: Part I.," Sveriges Geologiska Undersökning, Ser. C, no. 50.

His succeeding zone of *Monograptus gregarius*, containing also *Monograptus fimbriatus* and *Rastrites peregrinus*, is in the position of our zone of *M. fimbriatus*, which contains the same forms.

Above this is Tullberg's zone of *Monograptus convolutus*. It also contains *M. lobiferus*, *M. leptotheca*, *M. communis*, *Rastrites peregrinus*, and *Petalograptus folium*. All these forms occur in the *convolutus*-zone of the Lakes, except *R. peregrinus*, which is replaced by *R. hybridus*; there seems therefore to be no representative of the thin *argenteus*-zone in Scania.

The zones of *Petalograptus cometa* and *Monograptus spinigerus* are united together in Scania. Tullberg finds in this zone *M. spinigerus*, *M. intermedius* (=*discretus*, Nich.?), *M. Clingani*, *M. argutus*, *Diplograptus Hughesii*, and *Petalograptus cometa*.

The zone of *Rastrites maximus* is doubtfully represented. He refers certain shales seen at Tosterup with *Monograptus turriculatus* and *M. crispus* to this horizon; but we believe that this and the succeeding zone of *Monograptus uncinatus* are really referable to the Browgill Beds. The beds which Tullberg compares with the Gala Group of Scotland, and which are therefore comparable with the Browgill Beds, are (in ascending order):—The zones of *Cyrtograptus Grayæ*, Lapw., *Cyrtograptus? spiralis*, Gein., *Cyrtograptus Lapworthi*, Tullb., forming the base of his *Cyrtograptus*-beds. We feel doubt as to whether these are all separable from the two upper zones of his *Rastrites*-beds.

In our district *Cyrtograptus? spiralis* occurs abundantly below the band with *Cyrtograptus Grayæ*; but as the former species apparently ranges into the Wenlock Beds of Britain, it probably occurs in the representatives of the Gala Group, both above and below the band with *Cyrtograptus Grayæ*.

We just now alluded to the zone of *Monograptus cyphus* as being probably referable to our zone of *Dimorphograptus confertus*. In 1881, Baron Kurck described a section at the quarry of Bollerup which exhibits the zone of *Monograptus cyphus* and the base of the zone of *Monograptus gregarius*. From the *cyphus*-beds he records:—

Monograptus cyphus, *Lapw.*
—— revolutus, *Kurck.*
—— attenuatus, *Hopk.*
Dimorphograptus Swanstoni, *Lapw.*
—— cf. Swanstoni, *Lapw.*
Diplograptus tamariscus, *Nich.*
—— longissimus, *Kurck.*
Climacograptus undulatus, *Kurck.*
Discinocaris Brouniana, *Woodw.*

The second *Dimorphograptus* is described and figured, and agrees in every particular with a species described and figured by one of us in the Society's Journal for 1868*, under the name of *Diplograptus confertus*, Nich. The discovery of more perfect specimens has shown us that this is in reality a *Dimorphograptus*, and we have named the zone in which it occurs after it. In the *cyphus*-zone at Bollerup five species of Graptolites out of the eight recorded are found also in our zone, and we have no hesitation in asserting that the *Dimorpho-*

* "On the Graptolites of the Coniston Flags," Q. J. G. S. vol. xxiv. p. 526.

graptus-confertus zone of the Skelgill Beds is the British representative of the *cyphus*-zone of Bollerup. The lowest band of the *gregarius*-zone which is seen in the quarry at Bollerup contains *Monograptus triangulatus*, Harkn., and this is a reason for supposing that the section at Spengill, where beds with *Monograptus triangulatus* occur immediately above the *confertus*-zone, is complete.

In a former paper read before the Society in 1880*, one of the writers in describing the shales at the base of Barrande's band E. e. 1. in Bohemia, expressed the opinion that "not only does this zone represent the Birkhill Shales, but it can, like them, be divided into a series of subzones characterized by various species of Graptolites," though the actual succession of the zones was not determined. This opinion is justified by the researches of Dr. Tullberg who, in his 'Skånes Graptoliter,' when discussing the theory of "Colonies," gives the results of his examination of a series of specimens from these colonies, and from the corresponding beds at the base of E. e. 1. He recognizes the following zones :—

1. Zone of *Monograptus gregarius*, 2. Zone with *M. leptotheca* and *M. lobiferus*, 3. Zone with *M. turriculatus*, and 4. Zone with *Cyrtograptus*? *spiralis*, besides others of Wenlock and Ludlow age.

From Colonie Krejči he recognizes *Rastrites peregrinus*, *Monograptus gregarius*, *M. fimbriatus*, *M. triangulatus*, *M. lobiferus*, *M. leptotheca*, and *Climacograptus scalaris*.

This corresponds with the fauna of his *gregarius*-zone in Scania and of our *fimbriatus*-zone.

In Colonie Haidinger he finds *Monograptus lobiferus*, *M. triangulatus*, *M. convolutus*, *M. communis*, *Climacograptus scalaris*, *Diplograptus*, cfr. *folium*, *D. tamariscus*, and *Rastrites peregrinus*. He compares this with the fauna of his zone of *Monograptus leptotheca*, corresponding with ours of *M. convolutus*.

In Colonie D'Archiac he has recognized *Monograptus lobiferus* and *M. triangulatus* in one bed, *M. proteus* in another, and *Cyrtograptus*? *spiralis* in a third, and supposes that here are representatives of his zones of *M. leptotheca*, *M. runcinatus*, and *Cyrtograptus*? *spiralis*.

To these we would add the occurrence of the zones of *Monograptus spinigerus* and either *Rastrites maximus* or *Monograptus turriculatus* in the Colony of Hodkoviček, and of the former zone in the colonies D'Archiac and Haidinger.

Two specimens of shale from the Lower Palæozoic Beds of Hof, Bavaria, are mounted on a tablet in the Woodwardian Museum. These pieces contain the fossils of our zone of *Monograptus fimbriatus*, viz :—

Monograptus fimbriatus, *Nich.*	Rastrites peregrinus, *Barr.*
—— attenuatus, *Hofth.*	Diplograptus modestus, *Lapw.*
—— tenuis, *Portl.*	—— vesiculosus, *Nich.*
—— gregarius, *Lapw.*	Climacograptus normalis, *Lapw.*

A comparison of the non-Graptolitic fauna of the Stockdale Shales

* Q. J. G. S. vol. xxxvi. p. 604.

with that of similar beds is more difficult, but fully confirms the conclusions come to after examining the Graptolites.

The different forms of Phyllocarida might have been considered along with the Graptolites, as they occur in Graptolitic rocks.

Of these *Discinocaris* is found in the Birkhill Shales and their Bohemian equivalents; whilst *Peltocaris aptychoides* and *Aptychopsis Lapworthi* are also found in the Birkhill Shales.

Of the other fossils, *Encrinurus punctatus*, *Calymene Blumenbachii*, and *Leptæna quinquecostata* are found both in Llandovery Beds and in beds above and below them, whilst *Favosites mullochensis* occurs in the Llandovery Beds of the Girvan area.

Phacops elegans has been recognized in the Mulloch-Hill Sandstones (a specimen from this locality being preserved in the Woodwardian Museum) and in the corresponding beds at the Gasworks, Haverfordwest. It also occurs in the Gala Beds of Devil's Bridge, Aberystwith, where it was found some years ago by one of the authors.

In Norway it is common in the sandstones of stage 5β of Kjerulf, which correspond in lithological characters and fossil contents with the Mulloch-Hill Beds and the beds at the Gasworks, Haverfordwest. Dr. Schmidt records it from the Raiküll Beds of Russia, where it is found along with other fossils occurring in Kjerulf's 5β, and *Diplograptus esthonus* *. All these beds are admitted to be of Llandovery age, with the exception of the Devil's-Bridge deposit, which is compared with the Gala Group, and therefore indirectly with the Tarannon Shales. That some of the Trilobites occurring in our Skelgill Beds do pass up into the Browgill Beds seems clear from the occurrence of many of them in the calcareous band immediately below the Coniston Flags in Austwick Beck, and we have one specimen of *Phacops elegans* var. *glaber* from the Browgill Beds of Browgill, though its exact position was not ascertained. More Trilobites would probably be found in the Browgill Beds of the central area if the calcareous bands were further examined; for the carbonate of lime of these beds was probably derived from Trilobites, as in the case of the Trilobitic mudstones of the Skelgill group.

The examination of the occurrence of *Phacops elegans* shows that it is a Llandovery-Tarannon form, and it has not been recorded from earlier or later formations.

Phacops mucronatus, Brongn., occurs in the Llandovery Beds of Haverfordwest, and in the Upper Brachiopod Schists of Westrogothia. It is different from the form which occurs in the Ashgill Shales, and which seems to correspond with the form from the Lower Brachiopod Schists.

Orthoceras araneosum, Barr., is found in the Wenlock and Ludlow rocks of Britain, and in the beds of Barrande's Stage E, in Bohemia †.

The other fossils are new. Of these, *Ampyx aloniensis* belongs to

* Schmidt, 'Revision der ostbaltischen silurischen Trilobiten,' p. 43; and Q. J. G. S. vol. xxxviii. p. 526.

† Blake, 'British Fossil Cephalopoda,' p. 124.

a genus which is common in Ordovician rocks. Two species are, however, found in the Silurian, viz.:—*Ampyx parvulus*, Forbes, from the Lower Ludlow rocks of Ludlow, and *Ampyx Roualti*, Barr., from the corresponding beds of Bohemia. It is interesting to find another form which reduces the gap between the newest *Ampyx* of the Ordovician rocks and these diminutive forms of the Ludlow series.

The fauna that most nearly approaches our Trilobite fauna of the Stockdale Shales is found in the Tarannon Shales of the Onny River. A number of Trilobites from these beds are preserved in the Museum of Practical Geology, and we have examined the specimens; they are:—

Phacops glaber, n. var.
Cheirurus bimucronatus, *Murch.*
Encrinurus punctatus, *var.* arenaceus.
Calymene Blumenbachii, *Brongn.*
Illænus Thompsoni, *var.*
Proëtus nasiger, *Edgell*, MSS.
Acidaspis dama, *Fl. & Salt.*?

The first form occurs also in the Stockdale Shales; of the two latter, *Proëtus nasiger* is very near our *P. brachypygus*. It appears to possess a narrower tail, and larger basal lobes to the glabella. The specimen doubtfully referred to *Acidaspis dama* is near to our *A. erinaceus*. The glabella and free cheek only are seen in the specimens of the Museum of Practical Geology. The former is smooth, and the lobes are slightly different from our forms. The discovery of more specimens may prove that these distinctions are merely varietal in the case both of the *Proëtus* and of the *Acidaspis*.

VI. Remarks on the Bearings of the Results.

The Stockdale Shales have been shown to consist of from two-hundred and fifty to four hundred feet of alternating black and green shales, blue mudstones, often calcareous, and greenish-grey grits.

They are divisible into a Lower group, the Skelgill Beds, consisting mainly of dark Graptolite-bearing shales alternating with lighter mudstones, which are entirely devoid of Graptolites except where they pass into the adjacent Graptolitic shales, and an Upper group having from twice to three times the thickness of the Lower one (but probably formed much more rapidly, and therefore not of anything like the actual importance of the Lower group), consisting chiefly of green and purple shales with interstratified grit-bands, and a few insignificant seams of dark Graptolite-bearing shales.

The Stockdale Shales are furthermore capable of being divided into a series of zones, recognizable by their lithological characters and also by their contained fossils, these zones undergoing only a slight alteration in thickness and character when traced across the country.

The lowest zone has been shown to be entirely conformable to the Ashgill Shales below, there being no discordance of strike, and the same bed of the Ashgill Shales being seen, in several remote sections, with the lowest band of the Stockdale Shales resting directly upon it.

The apparent unconformity by which one of us was formerly deceived turns out, on examination, to be due to the existence of strike-faults. Although there is absolute conformity between the lowest beds of the Stockdale Shales and the highest beds of the Ashgill Shales, the palæontological break is complete, and it is at this point that we draw the line of division between the Ordovician and Silurian systems.

Similar conformity is seen between the top of the Stockdale-Shale series and the base of the succeeding Coniston Flags, the passage being rather a gradual one, however, instead of very sudden, as in the case of the junction at the base.

In all the sections described, with the possible exception of that at Spengill, the Lower Skelgill Beds are seen to be separated from the higher beds of the group by a strike-fault; and minor faults of a similar nature are seen at higher levels. That this fault does not remove any great thickness of rock is shown :—

(1) By the frequent juxtaposition of the zones of *Dimorphograptus confertus*, and *Monograptus fimbriatus*, which contain several species in common.

(2) More particularly by the resemblances between the above-named zones and two similar zones in the Moffat area, the zones of *Diplograptus vesiculosus*, Nich., and *Monograptus gregarius*, Lapw., and the relationship of the *M.-fimbriatus* zone to the lower portion of the latter. As the succession is complete in the Scotch region, no important zone of rock can be concealed in that of the Lake-district.

The occurrence of a fault of such wide extent exerting so little effect is remarkable, and we can offer proofs that the fault itself is not an ordinary one, but that it runs generally with the bedding, and that it is rather of the nature of a crush. The soft Skelgill Beds lie between the harder rocks at the summit of the Ordovician series and those of the Browgill group, and they must have given way during a process of stretching, which caused the upper beds adhering to the Browgill rocks to move over the lower beds, which have been shown to adhere to the Ashgill Shales. That such stretching has taken place is proved by the following facts :—

(1) The behaviour of the strike-fault with the beds. The outcrop of the Skelgill Beds is a sinuous one, being bent into V's in crossing the valleys, the apex of the V's always pointing down the valleys, as the dip of the beds is always greater than the slopes of the valley-bottoms. Moreover, these valleys are usually occupied by great dip-faults, which displace the beds laterally. In such cases the strike-fault would be found to affect different beds when crossing these valleys and shifted by the dip-faults, whereas it is always found to run along the narrow band between the Ashgill Shales and the Browgill Beds.

(2) The Skelgill Beds are often entirely, or almost entirely, removed. When developed in force, there is usually a section cut through them, and the narrow depressions occurring between the different sections and marked by a line of swamp, are bounded by

the Ashgill Shales or Coniston Limestone on one side and by the Browgill Beds on the other. The Ordovician and Silurian rocks usually approach so near to each other that it may readily be seen that there is no room for more than a small portion of the whole thickness of the Skelgill Beds in the interval. The beds are therefore now preserved as a series of lenticular patches, the main portion of the line of outcrop being occupied by little or none of them.

(3) Smaller crushes of a similar nature can often be traced in a single section, as, for instance, in the case already described of the crushing-out of the shales of the *argenteus*-zone below the Upper Bridge at Skelgill.

(4) The hade of the fault may frequently be actually seen coinciding with the dip of the beds; and the line of fracture is often marked by broken shale frequently further crushed into a black mud. Where the dip of the beds is different on the two sides of the fault, this is probably a local phenomenon produced by the rucking up of the lower beds during the process of sliding.

(5) The occurrence of a quartz-vein along the line of movement just below the promontory near the Upper Bridge at Skelgill, which coincides with the dip of the beds there, and the upper surface of which is completely polished by the shales which rest on it, shows that these shales have been moved over the nearly horizontal vein at this point.

(6) At the Lower Bridge at Skelgill it can be shown that some 15 feet more rock has been removed by the fault in the great cliff just above the bridge than in the section just below it. Between these two sections is the small dip-fault already described, which has a downthrow to the E.N.E. on the S.S.W. side of the stream, and one to the W.S.W. on the N.N.E. side. This looks as if the tearing away of the additional 15 feet of rock had been limited by a pre-existing joint-plane, and that on this side of the joint the lower and upper rocks had moved towards each other to fill up the gap so produced.

(7) It is probably due to the same process of stretching that the great dip-faults, which frequently cause a lateral shift of the Coniston Limestone to an extent of over half a mile, rapidly die out to the south, so that beds some two miles south of the Coniston-Limestone outcrop are scarcely affected.

It has been stated above that the beds of the Stockdale-Shale series undergo little alteration in character and thickness when traced laterally. This is well shown by the remarkably exact correspondence between the shales of the zone of *Monograptus argenteus*, as seen in Skelgill and Mealy Gill. There is, however, a certain amount of lateral change, as shown clearly by the great thickening of the Browgill Beds between Stockdale Beck and Spengill. The variations of thickness, so far as we have been able to ascertain them by measurement, are indicated in the following table:—

	Poaka Beck.	Appletree-worth Beck.	Torver Beck.	Mealy Gill.	Yewdale Beck.	Skelgill.	Stile End.	Browgill.	Spengill.
Crispus-zone to *Turriculatus*-band	...	...	30′ (about)	...	...	...	...	21′ 8″	15′ seen
Turriculatus-bands and included mudstones	...	...	1″	1″ ?	...	...	...	1″	35′ 4″
Pale shale below lowest *Turriculatus*-band	...	...	15′–20′	21′ ?	...	...	...	21′	26′
Maximus-zone	...	...	0	...	0	0	...	0	24′ 8″
Erinaceus-zone	6′ seen	...	10′	8′ seen	10′	10′	...	10′	30′ (about)
Spinigerus-zone	2′ 2″	2′ 6″ (about)	2′ 3″	3′ (about)	2′	3′ 6″	...	2″ (about)	2′ seen
Aloniensis-zone	1′	2′ 6″ (about)	...	...	4′ seen	4′ 6″	...	1′ 5″	
Clingani-band	8″	...	...	...	...	1′	1′	3′	
Barren band	2′ 4″ seen	...	...	...	...	3′ 6″	2′ 10″	2′	
Convolutus-zone	...	...	...	...	...	7′ 9″	7′ 4″ seen	4′ seen	
Glaber-zone	...	10′ (about)	...	...	...	12′	...	...	4′–5′ seen
Argenteus-zone	...	...	...	6″	...	8″	...	...	
Punctatus-zone	...	...	...	4′ seen	...	5′	...	...	
Fimbriatus-zone	...	...	...	7′ 6″ seen	...	7′ 3″ seen	...	...	many feet
Confertus-zone	...	...	...	...	...	7′–8′ seen	...	1′ seen	about 25′ seen
Acuminatus-zone	...	3″	...	...	...	9″	...	2′ 6″	6″

An examination of this table shows a general thickening-out of the beds eastward. There are doubtless some errors in it, owing to difficulties of measurement; for instance, we feel that the thickening of the *Clingani*-band from one to three feet in crossing the valley of Long Sleddale is unlikely, and the apparent increase may be due to our having included shaly mudstones in this bed at Browgill.

Some of the variations may also be due to a greater compression of beds in one locality than in another, and to portions having been torn away without our detecting it, which is very possibly the case in some instances where the section is not very clean-cut. But with these allowances, the fact of a general thickening to the east remains apparent, and is especially marked in those beds which must have accumulated with considerable rapidity. The great increase in thickness of the zones of *Acidaspis erinaceus* and of *Monograptus turriculatus*, the appearance of new Graptolitic seams in the latter, and the incoming of the zone of *Rastrites maximus* in Spengill, illustrate this clearly. To what is this thickening eastward due?

It seems to suggest the existence of land in that direction; and we are inclined to connect this with the apparent unconformity in the Settle area, which possibly indicates the occurrence of land in that region during the formation of the Skelgill Beds, and during a portion of the period when the Browgill Beds were forming, though the *elegans*-limestone of Austwick Beck shows that that area was submerged, at any rate during the later portion of the Browgill times; but the calcareous conglomerate of Crag Hill may be actually at the base of the Coniston Flags, as the *elegans*-limestone has not been detected here.

We make this suggestion with diffidence at present; after a more detailed examination of other beds of this area, which we hope soon to accomplish, we shall be able to express an opinion upon this subject with greater confidence.

Another point to which any one who works in a series of beds like those which we have examined must have his attention called is the remarkable alternation of the Graptolitic Shales with other non-Graptolitic beds. To what is this due? to recurrent climatic change, or to difference in the character of the sea-floor? One of us has discussed this question in a paper which appeared in the 'Proceedings of the Cambridge Philosophical Society' (Proc. Camb. Phil. Soc. vol. vi. pt. ii.), and gives reasons which induce him to consider it as due to climatic change. Without entering into this question here, we would call attention to another difficulty. Is the apparent absence of Graptolites in the Trilobite-bearing mudstones, and of Trilobites in the Graptolitic shales, due to the migration of the latter organisms from the area during the formation of these shales, and to the disappearance of Graptolites from the area during the formation of the mudstones? or did the forms linger on in the area in diminished numbers during the period that was unfavourable to their existence? We cannot offer any satisfactory evidence on this point, but we believe that both events went to produce the observed results. We

do find Graptolites rarely preserved in the mudstones, and though we have hitherto found no Trilobites in the Graptolite-shales, occasional Brachiopods and corals have turned up. In Dalecarlia one of us has seen Trilobites preserved in some of the Graptolite-bearing representatives of the Stockdale Shales. Such a lingering-on under unfavourable conditions would be admirably qualified to bring about that variation in the creatures which would account for the marked contrast between the fossil contents of beds separated only by a few feet of intervening rock.

On the other hand, the occurrence of a zone in Scania with an intermixture of the forms of the zones of *Petalograptus cometa* and *Monograptus spinigerus* tends to indicate that there may have been also migration from one region to another during a time unfavourable to the existence of a group of organisms in the former, and that in this way an intermixture of two faunas elsewhere separated would result, but our present experience tends to show that this is somewhat rare.

With regard to the age of the Stockdale Shales, we shall say little, as we consider the question fully settled. They are conformable to the Ordovician beds below and to the Wenlock beds above; and this indicates that they represent the two Llandovery subdivisions and the Tarannon shales, in other words that they belong to the series for which Professor Lapworth has suggested the name Valentian.

Our comparison of the beds with those of other areas entirely supports this view. The Birkhill Shales have been referred by Professor Lapworth to the Lower Llandovery, in his paper on "The Moffat Series." But the same author has also shown that the Gala Beds, the equivalents of our Browgill Beds, represent the Tarannon Shales; in which case, the Birkhill Shales and the corresponding Skelgill Beds must include representatives of both Lower and Upper Llandovery; and this is the view taken by Professor Lapworth, in his subsequently published paper on "The Geological Distribution of the Rhabdophora," where he describes the Birkhill Shales and Gala Group under the title "Valentian or Llandovery-Tarannon Formation."

The fossils of the Stockdale Shales support this to the fullest extent. Many of the Graptolites and of the higher organisms are exclusively limited to representatives of the Valentian formation in other areas, and there are very few which transgress the limits of this group.

The most important result of our researches is the additional evidence which we have furnished of the value of Graptolitic zones as a means of comparison of Lower Palæozoic rocks of distant areas. We have long looked with admiration on the remarkable results of Professor Lapworth's detailed researches upon these rocks, and have for many years been convinced of the importance of his results. We have watched with pleasure the adoption of his views and of his methods of working by the enthusiastic geologists of Scandinavia. We must confess, with disappointment, that we have frequently heard British geologists express themselves in words of hesitation con-

cerning the importance of the Graptolitoidea as a means of advancing the comparative study of the stratified deposits, and we sometimes feel that Dr. William Smith's dictum as to strata identified by their organized fossils is little heeded in Britain, so far, at any rate, as the Lower Palæozoic rocks are concerned. If we have added a grain to the weight of evidence that has been accumulating in ecent years, as to the widespread uniformity of fossil-zones among these rocks, we have not laboured in vain.

§ VII. Description of Fossils.

The Graptolitic fauna of the Stockdale Shales is one which is sufficiently well known by the researches of Prof. Lapworth; and we have not added any new forms during our recent researches.

The other fossils are chiefly Trilobites, though a few Corals and Brachiopods also occur.

We append notes upon the new forms and those which have not hitherto been described from British deposits. The Trilobites are difficult to obtain in a good state of preservation, and it would probably require many years' patient collecting to obtain perfect specimens of all the forms. Under these circumstances we have refrained at present from minute descriptions, and have drawn up brief diagnoses, which will, we believe, be sufficient to enable others readily to recognize those forms which it was necessary for us to notice on account of their importance as indices to the various non-Graptolitic zones.

The Coral-fauna of the Stockdale Series is a very limited one, as regards both the variety of species represented and the number of individuals. The Upper Skelgill Beds have yielded an undeterminable species of *Lindstrœmia*, and a Monticuliporoid has been found in the *acuminatus*-zone in Skelgill. With these exceptions the known corals of the Stockdale Series are referable to the genus *Favosites*, and, mainly if not exclusively, to one species of the same, viz. *F. mullochensis*, Nich. and Eth. jun. This species occurs abundantly in the Silurian rocks of Ayrshire, at Mulloch Hill and at Woodland Point; and it is of not very uncommon occurrence in the zone of *Phacops glaber* in Skelgill.

Phacops (proper) elegans, Boeck & Sars. (Pl. XVI. figs. 1, 1 *a*, 2, 3, 3 *a*, 3 *b*.)

Trilobites elliptifrons, Esmark, "Om Nogle nye Arter af Trilobiter," Mag. for Naturv. Anden Række, Bd. i. p. 269.

Trilobites elegans, Sars & Boeck, Gæa Norvegica, p. 139.

Phacops quadrilineata, Ang. Pal. Suec. p. 12.

Phacops Stokesii, Nieszk. "Mon. Tril. d'Ostsee prov.," im Arch. für Nat. Liv- Ehst- und Kurl. ser. 1, Bd. i. p. 530.

Phacops latifrons, Eichw. Leth. Ross. vol. i. p. 1428.

Phacops elegans, Kjerulf, Veiviser, p. 20.

Phacops elegans, F. Schmidt, Rev. d. ostb. Tril. Mém. Acad. St. Petersb. sér. 7, Tome xxx. No. 1. p. 72.

Phacops elliptifrons, Törnq. "Undersökn. öfv. Siljans. Tril.," Sver. Geol. Unders. ser. C, no. 66.

We have compared the forms discovered in the Stockdale Shales with the figures of the Russian specimens, and with actual examples collected by one of us from the Llandovery rocks of Christiania, and they agree in every particular.

The species has frequently been confused with *Phacops Stokesii*, Milne-Edw., a form common in the Wenlock rocks. From this the present species differs in the shape and smoothness of the glabella, the possession of smaller eyes, and the convexity of the axis of the tail.

The incurved lower margin of the cheek possesses six cavities for the reception of the ends of the pleuræ (Pl. XVI. fig. 3 *b*). The interspaces between these increase in size anteriorly, as the posterior pleuræ, the ends of which are received by these, do not overlap one another so much as the anterior pleuræ, when the animal is rolled up. Indications of similar cavities are seen in a specimen of *Phacops Stokesii* from the Wenlock Limestone of Dudley, preserved in the Woodwardian Museum, and numbered $\frac{a}{887}$.

Hor. & Loc. Heads and tails of this species are common in the *Phacops-glaber* and *Ampyx-aloniensis* zones of Skelgill, the latter zone of Browgill, the *Acidaspis-erinaceus* zone of Torver Beck and Spengill, and the calcareous bed of Austwick Beck. It is a common Llandovery fossil in many parts of Britain and the continent.

Phacops (proper) elegans, var. nov. glaber. (Pl. XVI. fig. 4.)

Tail $\frac{1}{2}$ inch broad, $\frac{1}{4}$ inch long. Axis one fifth the width of the whole tail, tapering gradually, and extending about two thirds the length of the tail; marked with two very deep prominent furrows anteriorly, and four or five obscure ones posteriorly. Limb marked by two slight furrows on either side, the under surface exhibiting a thick recurved margin.

These broad tails are very abundant in one horizon of the Skelgill Beds, and less common in others. They are easily distinguishable, by their great breadth and extreme smoothness, from the tails of the typical *P. elegans*; but one or two intermediate forms would indicate that the present Trilobite is but a variety of the normal form.

A single head, apparently belonging to this variety, and differing from the ordinary form in the size of the eye and some details of the shape of the glabella, is too imperfect to figure.

The specimens indicate a Trilobite which, when complete, must have measured an inch and a half in length, thus greatly exceeding that of *Phacops elegans* proper.

Hor. & Loc. Common in the *glaber*-zone of Skelgill; rare in the *aloniensis*-zone of Skelgill and Browgill.

Phacops (Dalmannites) mucronatus, Brongn. (Pl. XVI. figs. 5, 6.)

Entomostracites caudatus, Wahl. Nov. Act. Soc. Upsal. vol. viii. p. 25.
Asaphus mucronatus, Brongn. Crust. Foss. p. 24.
Asaphus mucronatus, Dalm. Vet. Akad. Handl. 1826.
Asaphus mucronatus, Hisinger, Lethæa Suecica, p. 13.
Phacops mucronata, Ang. Pal. Scand. p. 10.
Phacops mucronata, Emmr. Neues Jahrb. 1845.

The Lake-district form, so far as we can make out from the somewhat scanty material we possess, corresponds in every particular with specimens of *P. mucronatus* obtained by one of us from the upper part of the Brachiopod-schists of Westrogothia, which occupy a corresponding position to that of the Stockdale Shales. It seems to differ from the poorly preserved form described by Salter (Mon. Brit. Tril. p. 46).

Hor. & Loc. Heads and tails of this Trilobite are not rare in the zone of *Ampyx aloniensis* at Browgill. A fragment of tail, possibly referable to the same species, has been discovered in the Barren Band at Skelgill.

Cheirurus bimucronatus, Murch., var. nov. acanthodes. (Pl. XVI. figs. 7, 8.)

Head less than $\frac{1}{4}$ inch long. Glabella with basal lobe circumscribed, the furrow well marked in front, shallower behind. Middle and upper furrows as in the normal form. Eye opposite the upper lobe. Facial suture cutting the posterior margin far forward. Posterior angle of the cheek produced into a curved spine at least as long as the glabella. Tail, with a short axis possessing two well-marked furrows. Limb slightly furrowed, the border produced into three prominent spines on each side.

This form differs from the Wenlock species not only in possessing the elongated spines to the cheek and tail, but also in the forward position of the eye, and the point where the facial suture cuts the lateral margin. In these respects it agrees with a specimen from the Llandovery rocks of Llandovery, figured by Salter (Mon. Brit. Tril. pl. v. fig. 4), the original of which is in the Woodwardian Museum, which also may have possessed the elongated spines. We suspect that several forms which have been referred to Murchison's species are really distinct, but in the meantime prefer to keep the well-marked little Trilobite from the Stockdale Shales (which must have attained a length not much exceeding one inch) under this specific name, merely giving it a varietal distinction.

Hor. & Loc. Zone of *Phacops glaber*, Skelgill; zone of *Ampyx aloniensis*, Skelgill and Browgill; zone of *Acidaspis erinaceus*, Spengill; Calcareous band, Austwick Beck.

Cheirurus (Pseudosphærexochus) moroides, n. sp. (Pl. XVI. figs. 9, 10, 10 *a*.)

Glabella, length 5 lines, width 4 lines, widest in the centre. Neck-lobe not preserved. Basal lobe circumscribed, elliptical, rather broader than long, occupying more than one third the entire width of the glabella, basal furrows very deep and defined: middle furrow moderately deep, extending about $\frac{1}{3}$ of the way across the glabella; upper furrow much shorter and not so strongly defined. Middle lobe shorter than basal, and slightly larger than upper. Frontal lobe short.

The whole glabella very convex, and uniformly marked with very large granules, between which are smaller ones and a third series yet smaller.

Only two imperfect specimens, displaying portions of the glabella,

have, so far, been discovered, but they are sufficient to show that the species is clearly distinct from *C. granulatus*, Ang., *C. conformis*, Ang., and *C. Rœmeri*, Schmidt (the forms which it most nearly resembles), in the characters of the basal lobe and the details of the ornamentation.

Hor. & Loc. Rare in the *Phacops-glaber* zone of Skelgill.

Acidaspis erinaceus, n. sp. (Pl. XVI. figs. 11, 12.)

Length $\frac{1}{5}$ inch. Head twice as broad as long, front produced, smooth; sides ornamented with several short spines. Glabella tumid, the central portion broadest in the centre, flanked on either side by two circumscribed lobes, of elliptical shape, the posterior one being the larger. Eyes and course of facial suture not clearly defined in the specimens. Posterior angles produced into long spines curving outward and backward. Neck-lobe large, with lateral tubercles, each giving off a stout short spine, and having a large granule in its centre. Entire head ornamented with coarse granules.

Body-rings 8 in one of the two nearly complete specimens discovered, and 6 in the other less mature one. Axis with marked tubercles at the extremities of the rings; pleuræ (omitting spines) nearly twice as wide as axis, consisting of an anterior smooth portion, and a posterior ridge ornamented with two granules on each pleura. The ridge is bent back at the outer margin to form a long slender spine at least as long as the body of the Trilobite.

Tail having a short axis of two rings with prominent tubercles. Limb ornamented with ten spines as follows:—two very short anterior ones on each side, succeeded by a very long pair connected with the axis by raised ridges. Each marked with a tubercle. Behind this is a short pair and, lastly, a larger pair, all of these being directed backwards.

This species resembles *A. centrina*, Dalm. (=*A. granulata*, Ang.), from the same horizon in Sweden, but it differs from the latter, as shown in Angelin's figure, in the following particulars:—

The head has a produced front and a strongly granulated surface.

The rings of the axis have large lateral tubercles instead of a row of granules.

The tail differs in the disposition of the spines and the presence of a connecting-ridge between the large spine and the axis. It is true that Barrande has shown that the disposition of the tail-spines varies in the same species; but we possess a large number of tails of our form in which the arrangement is constant.

One of us has collected an *Acidaspis* from the Upper Brachiopod-schists of Olleberg, in which the spines appear to be disposed as in the present species.

Hor. & Loc. Very abundant in the zone of *Acidaspis erinaceus* at Torver Beck.

Harpes judex, n. sp. (Pl. XVI. figs. 13, 14, 14 *a*.)

Length probably $\frac{3}{4}$–1 inch.

Head semicircular, surrounded by a broad, very convex limb, of horse-shoe shape, prolonged backward into a blunt point.

Glabella almost circular, marked by a small pair of basal lobes extending over the fixed cheek as shallow depressions, which are stated by Barrande to characterize the genus. Eyes minute; no visible trace of an ocular ridge. The cheeks and limb are marked by a venose arrangement of narrow ridges, seen enlarged in fig. 14 *a*. Axis of body wide, pleuræ straight for the greater part, but slightly recurved at the extremities, marked by shallow, straight grooves.

This differs from all the Bohemian forms. It is near to *H. Wegelini*, Ang., but the glabella is broader, and the venose structure of the cheeks and limb is not shown in the figure of the Swedish species.

Our specimens have been subjected to so much pressure that the original structure is much obscured.

Hor. & Loc. Zones of *Phacops glaber* and *Ampyx aloniensis*, Skelgill, and in the latter zone at Browgill.

Harpes angustus, n. sp. (Pl. XVI. figs. 15, 16, 16 *a*.)

Head semioval, surrounded by a broad convex fringe, somewhat squared in front, extending backward towards the extremity of the body, where it terminates in a tolerably sharp point.

Glabella semicylindrical, reaching two thirds of the distance between the neck-furrow and the fringe, the space in front of it being occupied by a prominent tubercle. A furrow appears to occur on each side of the glabella, separating off a small basal lobe, which is not visible from above, being situate entirely upon the nearly perpendicular side. No depression is seen to extend from this on to the cheek. Eye small, situate near the anterior end of the glabella. Ocular ridge not shown. Cheeks and limb punctate, the puncta sometimes occurring in tolerably regular lines, and thus originating a venose structure, which is less prominent than in the last-described species.

About fifteen body-rings preserved in one specimen; axis very narrow and convex. Pleuræ nearly four times the width of the axis, almost straight throughout, and with a shallow groove. Tail unknown.

This is a much narrower form than the last, from which it differs in other particulars, so that it seems improbable that we have here merely differences of sex.

Hor. & Loc. Zones of *Phacops glaber* and *Ampyx aloniensis*, Skelgill.

Ampyx (Rhaphiophorus) aloniensis, n. sp. (Pl. XVI. fig. 17.)

Length, exclusive of spines, $\frac{1}{8}$ inch.

Head broader than long; glabella trapeziform, produced in front into a slender spine. Neck-segment very narrow. A pair of basal furrows, nearly parallel with the neck-furrow, produce a pair of well-defined though small basal lobes. Indications of a second pair of furrows running obliquely downward may be accidental. Posterior angle produced into a long spine, about $\frac{1}{4}$ inch long.

Body-rings badly preserved, four only seen; the pleuræ twice the width of the rings of the axis, marked by straight furrows

Tail very short and wide, apparently with two rings to the short conical axis.

This species is allied to *A. setirostris*, Ang., and *A. Rouaulti*, Barr. From the former it differs in its greater width and smaller size; from the latter in the character of the glabella-furrows and its broader axis. *Ampyx parvulus*, Forbes, has many differences from our form.

Hor. & Loc. Zone of *Ampyx aloniensis*, Skelgill and Browgill.

Proëtus brachypygus, n. sp. (Pl. XVI. figs. 18, 19.)

Length $\frac{1}{4}$ inch, width $\frac{1}{5}$ inch.

Head $\frac{1}{3}$ length of the whole creature. Glabella parabolic, with two small circumscribed basal lobes.

Body $\frac{1}{2}$ length of the animal, 8 segments. Axis wide, rather flat, with tuberculate extremities to the rings. Pleuræ slender, strongly grooved.

Tail three times as broad as long. Axis tapering rapidly, and extending two thirds the length of the tail, with 2–3 conspicuous rings. Limb gently rounded, marked with three or four prominent furrows.

We have found two nearly complete specimens of this minute form, which, though indifferently preserved, are quite unlike any other form of *Proëtus* which we know. The breadth of the whole creature, the width of the axis, and the short broad tail are very distinctive features. Isolated tails, apparently referable to this species, are tolerably abundant.

Hor. & Loc. Not uncommon in the *Ampyx-aloniensis* zone of Skelgill; one specimen in the same zone of Pull Beck, near Ambleside.

Atrypa flexuosa, n. sp. (Pl. XVI. figs. 20, 20 *a*, 20 *b*.)

Shell heart-shaped, with a fairly deep sinus.

Ventral valve with a small, prominent, pointed beak; sinus deep, with a short tongue-shaped extension, and marked by eight prominent, longitudinal ribs. Ribs less strongly marked on the convex portions of the valve. About 14 rather prominent, transverse laminæ of growth.

Dorsal valve with a very elevated mesial fold, the longitudinal ribs and transverse laminæ well developed over the whole of the surface.

Length $\frac{3}{4}$ inch, width $\frac{3}{4}$ inch, depth $\frac{1}{2}$ inch.

This species is intermediate in character between *A. imbricata*, Sow., and *A. altijugata*, Lindstr. The sinus is narrower and deeper than in the former species, but wider and shallower than in the latter, from which it also differs by the possession of more strongly developed transverse laminæ of growth.

Hor. & Loc. Tolerably abundant in the *Atrypa-flexuosa* zone of the Lower Skelgill Beds, at Skelgill.

List of Species.

	Zone of *Monograptus crispus.*	Zone of *Monograptus turriculatus.*	Zone of *Rastrites maximus.*	Zone of *Acidaspis erinaceus.*	Zone of *Monograptus spinigerus.*	Zone of *Ampyx aloniensis.*	Band with *Monograptus Clingani.*	Barren Band.	Zone of *Monograptus convolutus.*	Zone of *Phacops glaber.*	Zone of *Monograptus argenteus.*	Zone of *Encrinurus punctatus.*	Zone of *Monograptus fimbriatus.*	Zone of *Dimorphograptus confertus.*	Zone of *Diplograptus acuminatus.*
Rastrites distans, *Lapw.*		*													
—— gemmatus, *Barr.*					*										
—— hybridus, *Lapw.*			*												
—— maximus, *Carr.*															
—— peregrinus, *Barr.*					*										
—— urceolus, *Richter*															
Cyrtograptus Grayæ, *Lapw.*															
—— ? spiralis, *Geïn.*															
Monograptus argenteus, *Nich.*											*				
—— argutus, *Lapw.*															
—— attenuatus, *Hopk.*													*		
—— broughtonensis, *Nich.*														*	
—— Clingani, *Carr.*							*				*				
—— communis, *Lapw.*															
—— convolutus, *His.*									*		*				
—— crenularis, *Lapw.*									*		*				
—— cyphus, *Lapw.*									*		*		*		
—— crassus, *Lapw.*															
—— crispus, *Lapw.*	*														
—— distans, *Portl.*					*		*								

—— discretus, *Nich.*	...	...	...	...	...	...	...	...	*	...	*				
—— exiguus, *Lapw.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
—— fimbriatus, *Nich.*	...	...	*												
—— gregarius, *Lapw.*	...	...	*	...	*	...	*	...	*						
—— griestonensis, *Nicol.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
—— Hisingeri, *Carr.*	...	...	...	...	*?	...	...	...	...	...	...	...	...	...	*
—— involutus, *Lapw.*	...	...	...	...	*	...	*								
—— jaculum, *Lapw.*	...	...	...	...	...	...	...	...	*	...	*	...	*		
—— lobiferus, *M'Coy*	...	...	...	...	...	...	...	...	...	...	*	...	...	*	
—— leptotheca, *Lapw.*	...	*	*	...	*	...	*	...	...	...	*				
—— Nicoli, *Harkn.*	...	...	...	...	*	...	*	...	*						
—— pandus, *Lapw.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
—— proteus, *Barr.*	...	...	...	...	...	...	*								
—— rectus?	...	...	...	...	...	...	...	...	...	...	...	...	...	*	
—— revolutus, *Kurck*	...	*													
—— Sandersoni, *Lapw.*	...	*	*												
—— spinigerus, *Nich.*	...	...	...	...	...	...	...	...	*	...	*				
—— tenuis, *Portl.*	...	*	*	...	*										
—— triangulatus, *Harkn.*	...	...	*												
—— turriculatus, *Barr.*	...	...	...	...	...	...	...	...	...	...	...	...	...	*	
—— discus, *Törnq.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
—— concinnus, *Lapw.*	...	...	*												
Dimorphograptus confertus, *Nich.*	...	*													
—— elongatus, *Lapw.*	...	*													
—— Swanstoni, *Lapw.*	...	*													
Petalograptus cometa, *Gein.*	...	...	...	...	...	...	*								
—— folium, *His.*	...	...	...	...	...	...	*	...	*						
—— ovatus, *Barr.*	...	...	*	...	*	...	*	...	*						
—— ovato-elongatus, *Kurck*	...	...	*												
—— palmeus, *Barr.*	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*
—— var. tenuis, *Barr.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*

List of Species (continued).

	Zone of *Monograptus crispus.*	Zone of *Monograptus turriculatus.*	Zone of *Rastrites maximus.*	Zone of *Acidaspis erinaceus.*	Zone of *Monograptus spinigerus.*	Zone of *Ampyx aloniensis.*	Band with *Monograptus Clingani.*	Barren Band.	Zone of *Monograptus convolutus.*	Zone of *Phacops glaber.*	Zone of *Monograptus argenteus.*	Zone of *Encrinurus punctatus.*	Zone of *Monograptus fimbriatus.*	Zone of *Dimorphograptus confertus.*	Zone of *Diplograptus acuminatus.*
Diplograptus acuminatus, *Nich.*					*				*		*		*		*
—— Hughesii, *Nich.*															
—— longissimus, *Kurck.*															
—— modestus, *Lapw.?*					*				*		*		*		
—— sinuatus, *Nich.*					*		*		*		*		*		
—— tamariscus, *Nich.*					*		*		*		*		*		
—— vesiculosus, *Nich.*													*	*	
Climacograptus minutus, *Carr.*					*		*		*		*		*	*	*
—— normalis, *Lapw.*															
Retiolites Geinitzianus, *Barr.*					*		*		*		*		*		
—— perlatus, *Nich.*															
—— ——, var. obesus, *Lapw.*															
——, *cf.* macilentus, *Törnq.*															
Monticuliporoid ?					*		*		*		*		*		
Lindstrœmia, sp.															
Favosites mullochensis, *Nich. & Eth. jun.*															
—— sp.															
Dawsonia campanulata, *Nich.*															
Discinocaris Brouniana, *Woodw.*															

——, sp.	...	...	*													
—— gigas, *Woodw.*	...	...	...	...	*											
Peltocaris aptychoides, *Salt*	...	...	...	...	...	...	...	...	*							
——, sp.	...	...	...	...	...	...	...	...	...	...	*					
Aptychopsis Lapworthi, *Woodw.*	...	...	...	...	...	...	...	...	*							
Turrilepas	...	*														
Homalonotus?	*															
Encrinurus punctatus, *Wahl.*	...	...	...	*	...	...	...	...	...	*						
Acidaspis erinaceus, n. sp.	...	...	...	...	...	...	...	...	...	...		*				
—— sp.	...	...	...	...	...	...	...	...	...	*	...					
—— sp.	...	...	...	*	...	...	...	...	...	*						
Phacops elegans, *Boeck & Sars*	...	...	...	...	...	*	...	...	...	*		*				
—— ——, var. glaber	...	...	...	...	...	*	...	...	...	*	...					
—— mucronatus, *Brongn.*	...	...	...	...	...	...	...	...	...	*						
Cheirurus acanthodes, var. nov.	...	...	...	...	...	*	...	...	...	*		*				
—— moroides, n. sp.	...	...	...	...	...	*					...					
Calymene Blumenbachii, *Brongn.*	...	...	...	...	...	?	...	...	...	*						
Harpes judex, n. sp.	...	...	...	...	...	*	...	...	...	*						
—— angustus, n. sp.	...	...	...	...	...	*	...	...	...	*						
Ampyx aloniensis, n. sp.	...	...	...	...	...	...	...	...	...	*						
Proëtus brachypygus, n. sp.	...	...	...	...	...	...	...	...	...	*						
Illænus Bowmanni, *Salt*	...	...	...	...	...	...	...	...	...	...		*				
Atrypa flexuosa, n. sp.	*										...					
Leptæna quinquecostata, *M'Coy*	...	...	...	*	...	...	*	*	...	*						
——, *cf.* sericea, *Sow.*	...	...	...	...	...	...	...	..	...	*						
Whitfieldia tumida, *Dalm.*?	...	...	...	...	...	*	...	*								
Orthoceras araneosum, *Barr.*	...	...	*	*	*	...	...	...	...	...	*					

EXPLANATION OF PLATE XVI.

Unless otherwise stated, the figures are of the natural size.

Fig. 1. *Phacops elegans*, Boeck & Sars: internal cast of glabella, *Glaber*-zone, Skelgill, × 2.
1*a*. Ditto: a small tail, × 2.
2. Ditto: from a wax impression of intaglio of head and anterior body-rings, *Erinaceus*-zone, Torver Beck.
3. Ditto: internal cast of a nearly complete specimen, *Glaber*-zone, Skelgill.
3*a*. Ditto: glabella and cheek of the same specimen, from a wax impression of internal cast.
3*b*. Ditto: diagrammatic sketch of incurved lower margin of cheek of the same specimen, showing cavities for the reception of the extremities of the pleuræ, × 4.
4. Ditto, var. nov. *glaber*: internal cast of tail, *Glaber*-zone, Skelgill.
5. *Phacops mucronatus*, Brong.: internal cast of glabella, *Aloniensis*-zone, Browgill.
6. Ditto: tail from same zone and locality.
7. *Cheirurus bimucronatus*, var. nov. *acanthodes*: glabella and cheek, *Glaber*-zone, Skelgill, × 2.
8. Ditto: tail, restored, from a second specimen, same zone and locality.
9. *Cheirurus moroides*, n. sp.: from a wax impression of an external mould of the glabella, *Glaber*-zone, Skelgill, × 2.
10. Ditto: from a wax impression of an external mould of the glabella, *Glaber*-zone, Skelgill.
10*a*. Ditto: details of ornamentation of the same, highly magnified.
11. *Acidaspis erinaceus*, n. sp.: *Erinaceus*-zone, Torver Beck, × 2.
12. Ditto: a younger specimen, same zone and locality, × 2.
13. *Harpes judex*, n. sp.: slightly distorted, the wrinkles on the centre of the glabella being apparently due to this, *Aloniensis*-zone, Skelgill.
14. Ditto: a crushed head, showing the venose structure, *Glaber*-zone, Skelgill.
14*a*. Ditto: a portion of the same specimen, highly magnified.
15. *Harpes angustus*, n. sp.: head, and cast of portion of body, *Aloniensis*-zone, Skelgill, × 2.
16. Ditto; internal mould of head, *Glaber*-zone, Skelgill.
16*a*. Ditto: a portion of the same, highly magnified, showing punctations.
17. *Ampyx aloniensis*, n. sp.: from a wax impression of intaglio, *Aloniensis*-zone, Skelgill, × 3.
18. *Proëtus brachypygus*, n. sp.; from a wax impression of intaglio, *Aloniensis*-zone, Skelgill, × 2.
19. Ditto: *Aloniensis*-zone, Pull Beck, × 2.
20. *Atrypa flexuosa*, n. sp.: ventral valve, *Flexuosa*-zone, Skelgill.
20*a*. Ditto: the same specimen, dorsal valve.
20*b*. Ditto: ditto, anterior view.

Note.—In fig. 2 the axis should be extended through the lowest (imperfect) body-ring. In fig. 19 the glabella-lobes are made too wide.

Discussion.

The President observed that the more minute details of stratigraphical geology were as important as divisions of wider range, especially in the Palæozoic rocks. He referred in illustration to the work done in Bohemia by one of the Authors.

Prof. Lapworth looked forward to the day when the existence of these Graptolite-zones in Lower Palæozoic rocks would be generally acknowledged, and they would be employed as a basis for classifi-

cation and mapping. He remarked that the thin Moffat series of South Scotland represented the whole of the Llandeilo, Bala, and Llandovery formations in other regions. There was never any doubt as to the general age of the beds above and below these Stockdale Shales, but there had been a great controversy as to the age of the shales themselves, which the Authors had now settled. The zones they had detected in the Lake-district agree with zones already established in South Scotland, Wales, Scandinavia, &c., and it is clear that the ideas of correlation by means of such zones are destined to be generally accepted.

He commented on the small thickness of these Stockdale beds, but pointed out that they were represented by very great thicknesses of deposit elsewhere; thus the Browgills were represented by thousands of feet in the Gala group and the Tarannon, and the Skelgills by enormous thicknesses in Girvan and Central Wales. The Authors had accomplished a piece of work of the highest systematic importance. Further zone-work was required, and it would be followed by a remapping of many areas.

Prof. Hughes alluded to the enormous changes in the classification of the older Palæozoic rocks which resulted from Prof. Lapworth's researches in the Moffat area. He referred to the apparent absence of reappearances of fossils in the beds described, but pointed out an instance of such a reappearance of a group of fossils elsewhere. He noticed the absence of fossils in the upper Browgill Beds of Spengill, and speculated on the possible connexion of this with the red coloration of the rocks. He thought that we must not overlook the important question whether the application of the Graptolitic and Trilobitic *verniers* would give the same results. He contrasted our present knowledge with the state of things when he mapped that country.

Dr. Woodward noted the fact that in the case of these thin beds a fauna limited to a small thickness of them was found to extend through a much greater thickness of rock elsewhere. With regard to the relative value of fossils, he pointed out that we must make the most of what we can get.

Mr. Hopkinson had examined the beds many years ago, and, although he had not worked out the zones, his recollections of the general succession coincided with the views of the Authors.

Mr. Etheridge commented on the value of zones, and specially referred to Prof. Keeping's work in Central Wales, and that of Prof. Blake on the Kimmeridge beds of the north of France and the Yorkshire Lias.

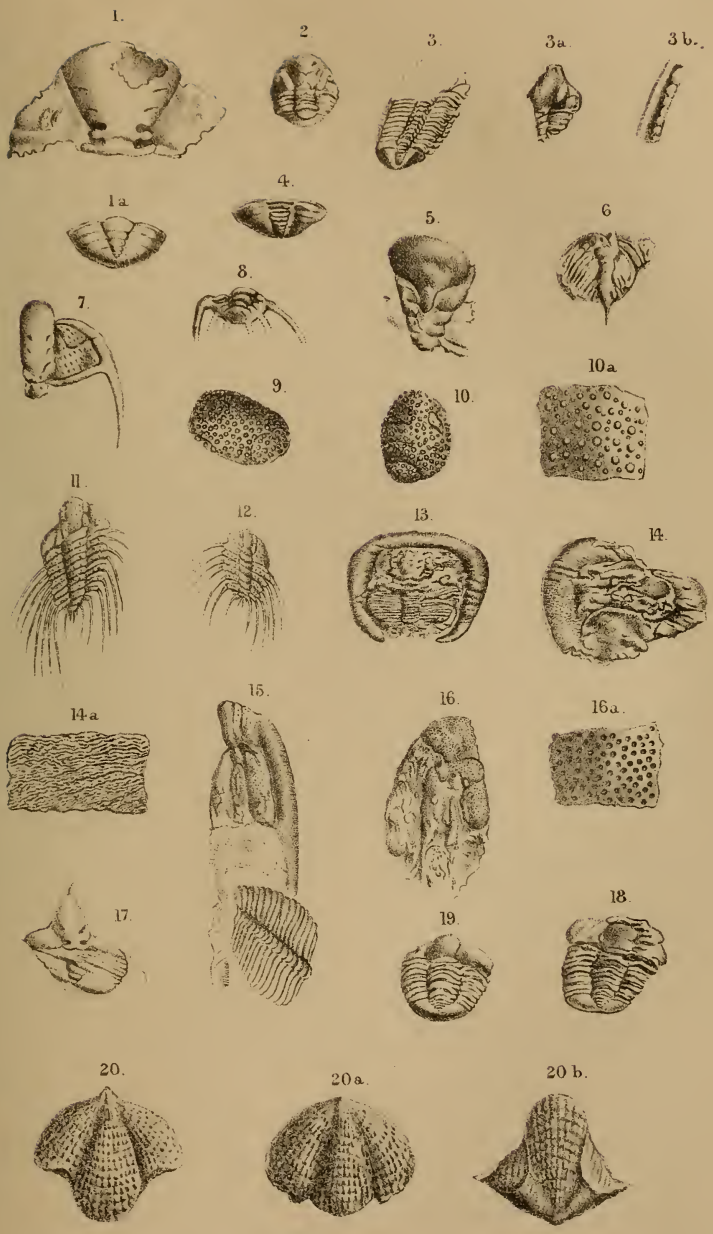
Dr. Hinde referred to the value of the large series of specimens exhibited in showing the characters of the rocks and fossils described.

Mr. Rutley pointed out the difficulty of restoring the physical geography of these early times.

Mr. Marr, in reply, pointed out that one peculiarity connected with Graptolites was the extremely slow accumulation of the deposits which usually contained them, as might be inferred from the remarks of

previous speakers on their mode of swelling out laterally into normal deposits of great thickness. Hence, although the forms had undoubtedly migrated from region to region, the time taken for migration was so short, as compared with the time taken for the accumulation of an appreciable thickness of sediment, that the film formed during the time of migration might be practically neglected.

He thanked the Society, on Prof. Nicholson's behalf as well as his own, for the way in which the paper had been received.



F. H. Michael del. et lith.

Mintern Bros. imp.

FOSSILS OF THE STOCKDALE SHALES